MEMORANDUM

To: Ms. Debra Rossi, RPM (USEPA Region III)

From: Theresa Miller, PG, LSP (Golder) and Michele Ruth, PE (RAI)

Date: June 1, 2018

RE: Response to Comments on Work Plan for Additional Investigation
Army Creek Landfill, New Castle County, Delaware

On behalf of New Castle County (NCC) and the Army Creek Private Settlors (ACPS), Ruth Associates Inc. (RAI) and Golder Associates Inc. (Golder) prepared this combined response-to-comments document for the Army Creek Landfill (ACL) Superfund Site (Site) located in New Castle County, Delaware. This document addresses the comments from the United States Environmental Protection Agency (USEPA), the Delaware Department of Natural Resources and Environmental Control (DNREC), and Groundwater Associates, LLC (GWA, on behalf of Artesian Water Company [AWC]) on the following documents:

- Work Plan for Additional Investigation (Work Plan) by RAI dated February 14, 2018 (RAI, 2018b)
- Sampling and Analysis Plan (SAP; included as Attachment 4 of the Work Plan) by Golder dated February 2018 (Golder, 2018)

Comments on the Work Plan and SAP were provided in the following documents as forwarded by the USEPA via email dated April 24, 2018:

- USEPA Region III and DNREC Comments via letter dated April 24, 2018 (USEPA, 2018b)
- USEPA Office of Analytical Services and Quality Assurance (OASQA) Comments via Memorandum dated April 13, 2018 (USEPA, 2018a)
- GWA Comments via letter dated March 1, 2018 (GWA, 2018)

The following sections set forth the written comments from the USEPA, DNREC, OASQA and GWA and the responses to those comments from the ACPS and NCC.

USEPA/DNREC Comments with ACPS and NCC Responses

Work Plan for Additional Investigation

USEPA/DNREC Comment 1. Background: The last paragraph discusses PFAS data in Attachment 2. A figure presenting the locations of the Attachment 2 sampling results should be include[d].

ACPS and NCC Response to USEPA/DNREC Comment 1:
As requested, a figure (Attachment Figure 2-1) presenting the locations for the PFAS monitoring results provided in Attachment 2 of the Work Plan has been prepared and is attached. This figure will be included in revised Work Plan.

USEPA/DNREC Comment 2. Conceptual Site Model, Hydrogeology: It is reported there that "the Site is located in the up-dip, feather-edge of the Potomac Formation and its stratigraphy is represented by proximal, stream-deposited sands, silts, clays and gravels accumulated in an estuarine, marginal marine basin, with highly variable lateral and vertical distribution of sand, silt, clay and gravel. Figure 3 provides the conceptual stratigraphic column described herein. The Columbia rests unconformably upon the upper portion of the UPA." The document continues with a description of the regional hydrogeology and current and historical aquifer use. However, it does not describe the Site-specific hydrogeology. Where is the landfill located? On top of or within the Columbia Aquifer or the UPA? Is the UPCU present beneath or adjacent to the landfill or in the area between the landfill and the supply wells? What are the thicknesses of the stratigraphic zones of interest? What is the depth of the groundwater table? In what formation is it present? Additional information is needed for adequate description of the CSM with respect to contaminant impacts to the groundwater.

ACPS and NCC Response to USEPA/DNREC Comment 2:
In response to this comment, the following text will be revised/added to the CSM:

Hydrogeologic Setting

Regional

The Site is located in the up-dip, feather-edge of the Potomac Formation and its stratigraphy is represented by proximal, stream-deposited sands, silts, clays and gravels accumulated in an estuarine, marginal marine basin, with highly variable lateral and vertical distribution of sand, silt, clay and gravel. Figure 3 provides the conceptual stratigraphic column described herein. The Potomac Formation is up to 600 feet thick, and is subdivided into Upper Potomac Aquifer (UPA), Middle Potomac Aquifer (MPA) and Lower Potomac Aquifer (LPA). The Columbia Formation rests unconformably upon the upper portion of the Potomac Formation. The Columbia Aquifer is separated from the UPA by the Upper Potomac Confining Unit (UPCU), a regionally thick, competent clay unit. There are occasional subcrop zones where the UPCU has been eroded away and replaced by sands, gravels and cobbles as evidenced by the presence of the Columbia basal gravel unit in areas where paleochannels exist. In the subcrop zones in the vicinity of the Sites, the Columbia Aquifer is in direct contact with the generally fining-upward sequence that is present between the UPCU and the top of the UPA upper sand, referred to as the Transition Zone, or UPCUTZ.

Within the UPA, which is the focus of this study, there is an intermittent clay unit referred to as the Upper Potomac Dividing Clay (UPDC), which separates the UPA into two sand units - the upper sand (US) of the UPA and the lower sand (LS) of the UPA. Based on an oral report from AWC during the January 11, 2018 meeting, the UPDC was not observed during the recent advancement of a borehole for installation of replacement production well AWC-6R. This observation is consistent with descriptions by others that the UPDC can be intermittent.

Site-Specific

The ACL is located within a former sand and gravel pit that "was excavated with a dragline until a 'hard zone' reportedly was encountered. This zone, a local stratigraphic marker unit is generally an iron-cemented conglomerate which marked the base of the Columbia Formation or the top of the underlying Potomac clay. The Potomac clay deposits were probably not removed during the sand and gravel operation, because clay would have had a deleterious effect on the aggregate quality of the sand, and would have interfered with the operations of the sand plant." (Weston, 1986; pp. 1-13 to 1-14)

Refuse/waste placement began in the early 1960s, after sand and gravel excavation ceased, at the "eastern end and generally proceeded back toward the pit entrance on the west." (Weston, 1986; p, 1-14) According to the Weston FS (1986):

> *"All intermittent cover material was obtained within the pit from residual sand, tailing piles, and siltation basin deposits. It is reported that as time progressed, cover material and landfill space became critically depleted; this situation may have encouraged deeper excavation, especially in the western end of the pit. This excavation probably removed various thicknesses of the confining clay overlying the Potomac sands. This practice probably created direct routes for the leachate from the landfill to enter the Potomac sands. However, the lithology of the upper part of the Potomac Formation near the landfill is so variable that at least some natural sand channels in the Potomac Formation were in direct contact with the overlying Columbia sands." (Weston, 1986; p. 1-14)*

From the Clean Tech Five Year Evaluation Report (FYER; Clean Tech, 2000), "In the vicinity of the landfill, the Columbia may be up to 60 feet thick. However, in two locations within the former gravel pit that became Army Creek landfill, Columbia gravels may have been excavated to the Potomac Formation (Weston 1986)" (Clean Tech, 2000; p. 43)

As presented in the Clean Tech FYER, "[i]n the area north of the landfill, the clay layer is completely absent; while immediately south of the landfill the clay layer varies in thickness from 10 feet to over 100 feet (Weston-1986). In the vicinity of the landfill, the top of the Potomac typically is a clay layer that acts to hydraulically isolate the Potomac sands from the overlying Columbia sands and gravels. Where the clay layer is either absent or not well developed, vertical cross-formation groundwater flow may be significant." (Clean Tech, 2000; pp. 43-44)

"The Feasibility Study (FS) (Weston, 1986) determined that a continuous, well developed clay layer exists at the top of the Potomac both in the western portion of the landfill and the area immediately north of the western portion of the landfill. The clay which has relatively low permeability, acts as a barrier to vertical groundwater flow, resulting in lateral groundwater flow within the overlying Columbia formation in the zone of saturated refuse." (Clean Tech, 2000; p. 44) Based on available logs (of varying quality) for borings advanced between the Western Lobe and the Llangollen wellfield, the UPA ranges in thickness from approximately 50 to 100 feet thick with intermittent clays (potentially representative of the UPDC).

Current Setting

The Columbia Aquifer groundwater is recharged by precipitation, with the exception of the capped area of the Site which is designed to reduce infiltration. The localized groundwater flow direction within the Columbia Aquifer is generally toward Army Pond and Army Creek, which discharges to the Delaware River to the northeast of the ACL Site. (Clean Tech, 2000)

Based on Weston's FS[1] for the ACL (Weston, 1986; p. 1-16), the water table is within the Columbia Aquifer and the landfilled materials. According to Weston, the western portion "and the area north of the western portion of the landfill generally has a continuous clay floor of relatively low permeability which acts as a barrier to vertical flow. As a result, there exists a relatively thick zone of saturated refuse in this portion of the landfill … Lateral *ground-water infiltration to the landfill is occurring on the northwestern margin of the landfill."*

These observations are supported by the Clean Tech 2000 FYER[2], which provided groundwater elevations within the Columbia Aquifer, the Potomac Formation and the landfilled materials of the Western Lobe (the report also evaluates the Eastern Lobe, but as that area is not a focus of the additional investigations requested for the ACL Site, that information is not included herein). Data provided from the June 1999 sampling event showed that water levels in the Western Lobe ranged from 16.9 to less than 9.5 feet-mean sea level (ft-msl), with the elevation of Army Creek in the vicinity of the Western Lobe at approximately 4 ft-msl. (Clean Tech, 2000; p. 53) These water-level data suggest that there may be lateral flow from the Columbia Aquifer directly into Army Creek in this area.

Although lithologic data is unavailable for locations immediately beneath the landfill itself, water-level data from the Western Lobe gas vents do not show a hydraulic connection between the water within the landfill and he underlying UPA. Water-level data collected by RAI from 2004 to 2007 (see Attachment 3; RAI, 2007), during the pilot suspension of the ACL recovery system, show that the water levels measured in the gas vents were relatively steady and higher than the water levels observed in the nearby Potomac wells, which are influenced by regional pumping from the Llangollen Wellfield (see Figure 4). Columbia water levels for wells outside the landfill during this same period indicate groundwater flows within the Columbia Aquifer from northwest to southeast, and there is a downward gradient from the Columbia Aquifer to the UPA (see Figure 5).

Prior to the groundwater withdrawals in this area, the natural groundwater flow in the UPA was toward the Delaware River, located to the east of the Site. The general groundwater flow direction in the UPA is to the south/southeast toward the AWC's Llangollen Wellfield, and the presumed dominant direction of groundwater flow downgradient of ACL's Western Lobe is shown in Figure 2.

The UPA is a confined aquifer except in areas near the subcrop zones where the UPA is semi-confined because the UPCU is absent or more permeable. There is generally a strong downward vertical gradient from the Columbia to the UPA, and between the UPA upper sand to the UPA lower sand, due to extraction, predominantly from the UPA lower sand, by AWC at its Llangollen Wellfield.

Footnotes:

[1] In 1986, the conditions at the Site were different than today in that the cap had not been installed on the ACL, the NCC groundwater recovery system was in operation near the ACL and AWC's Llangollen wellfield was extracting groundwater at a higher rate than today.

[2] In 2000, the conditions at the Site were similar with the exception that the NCC groundwater recovery system was in operation near the eastern lobe of the ACL. The ACL was capped in 1996 and AWC's Llangollen wellfield was extracting groundwater at a generally similar rate as today.

USEPA/DNREC Comment 3. Conceptual Site Model, Surface Water: Since necessary information regarding the Site-specific hydrogeology was not provided, it is not clear how groundwater impacted by the landfill interacts with the surface water (e.g., is the Columbia present adjacent to or under the landfill?). The discussion states that UPA groundwater does not discharge to the Columbia Aquifer or surface water. The discussion should also address interaction between the Columbia Aquifer and surface water. The reference(s) that explore and demonstrate interaction between groundwater and surface water should be cited.

ACPS and NCC Response to USEPA/DNREC Comment 3:

In response to this comment, the following text will be revised/added to the CSM:

Surface Water
Army Creek is the nearest surface water body to ACL. Army Creek flows along the southwestern corner of the ACL, then flows to the northeast into Army Pond located along the southeastern extent of the ACL. Army Pond/Creek flows to the northeast past the northeastern extent of ACL and continues through a marsh complex prior to flowing to the east into the Delaware River.

"Groundwater originating from the Columbia Aquifer upgradient of the landfill moves through the refuse under the cap[3] discharging partially to Army Creek Pond. However, based on ecological studies of Army Creek Pond, there is no present impact on the pond from the landfill, and as stated [above], the recovery well water quality [which was discharged to surface water until 2004] at the Site has improved since the cap was constructed." (Clean Tech, 2000)

Surface-water samples collected over the past 14 years, as part of the monitoring program for the ACL Site, consistently demonstrate that the surface water in Army Creek is not adversely impacted by the ACL. Historical surface water monitoring results for monitoring conducted through 2017 (RAI, 2018a) are provided in Attachment 4. There are no known or documented surface-discharge points for the impacted UPA groundwater associated with the ACL since shutdown of the groundwater-recovery system. Based on the strong downward gradients between the Columbia Aquifer and the UPA, discharge of UPA groundwater to the Columbia Aquifer and/or surface water does not occur.

Footnote:
[3] "The historical sampling of the recovery wells, which are the closest to the landfill (and therefore the best locations to evaluate leachate quality), indicate that the water quality has improved since the cap has been constructed and the current groundwater collection and treatment system has been operational." (Clean Tech, 2000) During operation of the recovery wells, the majority of extracted groundwater recharged the UPA and/or Army Creek because the treated groundwater was discharged to Army Pond. Additional information is available in Clean Tech's 2000 FYER.

USEPA/DNREC Comment 4. Approaches and Methodologies, Western Lobe Study: It is unclear why there are no wells in the upper or lower sands downgradient of the landfill in the area between wells P4 and 38 (in the eastern portion of the blue arrow indicating presumed flow towards the water supply wells). It is recommended that an additional well cluster is added in this area.

ACPS and NCC Response to USEPA/DNREC Comment 4:
The scope of this initial phase of work was discussed by the USEPA, DNREC, the ACPS and NCC during a series of conference calls and during an all-hands meeting at the DNREC offices on January 11, 2018. As discussed during the January 11, 2018 meeting, the locations for the proposed wells are considered "Phase 1" in evaluating the nature and extent of groundwater impacts downgradient of the Western Lobe, and it is anticipated that there will be a "Phase 2" after results of the "Phase 1" drilling and groundwater monitoring are evaluated. As discussed during the meeting, the best and most efficient way to proceed was to implement this scope of work first, evaluate the results to get a better definition of groundwater flow patterns in the area and the distribution of impacts, then decide how best to proceed for the next phase of work. The Work Plan and associated SAP were prepared based on these conversations and the meeting.

In conjunction with this comment and our response and based on the recommendations of the USEPA/DNREC and GWA (see the USEPA/DNREC Comment 16 and GWA Comment/ Recommendation 3) regarding replacement of long-screen wells with short-screen (10-ft or less screen interval) well clusters, the Parties have re-evaluated the well network. As indicated above, *the Parties recommend that after performance and evaluation of the data from "Phase 1" that another well pair be installed during the first year of the "Phase 1" investigation. This approach is consistent with GWA Comment/ Recommendation 3 which states "[e]ventual replacement … should be considered". It is anticipated that the well pair will be installed between wells P-4 and MW-38N, and a recommendation for its location will be developed based on sampling data collected during the first three quarterly monitoring events, and provided to the USEPA for approval.*

USEPA/DNREC Comment 5. Approaches and Methodologies, Western Lobe Study: The monitoring program is summarized in Table 1, and the well locations and the general Western Lobe Study Area are shown in Figure 2. However, without understanding the stratigraphy, where the wells are screened and the lithology at the well location, it is difficult to evaluate the monitoring program. Please supply a table with this information.

ACPS and NCC Response to USEPA/DNREC Comment 5:
As requested, a table (Work Plan Table 2) presenting the screened interval and lithology for the monitoring locations listed in Table 1 of the Work Plan has been prepared and is attached. This table will be included in revised Work Plan. Available boring logs for the wells listed on Table 2 are attached to this response letter and will be included as Attachment 6 of the revised Work Plan.

USEPA/DNREC Comment 6. Approaches and Methodologies, Western Lobe Study Area, first bullet: Artesian wells AWC-2, AWC-6R and AWC-7 are important data points at the south end of the study area as implied in the text of the Work Plan. However, the wells are not identified as sampling points in Table 1 and Figure 4. These wells should be sampled. If they will be sampled under another program (e.g., by Artesian), this information should be provided in the Work Plan, as well as a description of the sampling/analytical methods for the program and an assessment of the data comparability.

ACPS and NCC Response to USEPA/DNREC Comment 6:
Ms. Susanna Mays (Administrator for ACPS) contacted AWC regarding this request. AWC collects samples monthly for analysis of iron and manganese, and will begin collecting samples quarterly for analysis of cobalt. AWC only collects samples from wells that are operating at the time of their monitoring event; therefore, it is unlikely that all three wells (AWC-2, AWC-6R, and AWC-7) will be sampled each month/quarter. Ms. Mays discussed addition of VOCs and cations/anions, including calcium, magnesium, potassium, sodium, ammonia, nitrate, nitrite, sulfate, sulfide, chloride, and bicarbonate, semi-annually for one year with AWC. Ms. Mays is awaiting a response from AWC about inclusion of these additional analyses.

As requested, Table 1 and Figure 4 (now designated Figure 6) have been revised to include the locations for wells AWC-2, AWC-6R, and AWC-7. We have also included AWC-G3R in the revised table and figure, which are attached and will be included in the revised Work Plan.

USEPA/DNREC Comment 7. Approaches and Methodologies, Western Lobe Study Area, second bullet: Justification should be added explaining the decision not to analyze for VOCs and anions all four quarters.

ACPS and NCC Response to USEPA/DNREC Comment 7:
We will include quarterly VOC analyses for the wells downgradient of the Western Lobe. After careful consideration of this request, the parties agree to analyze samples from the new wells for VOCs quarterly for one year, with samples for cations and anions being collected and analyzed

semi-annually, coincident with the ACL and DS&G semi-annual monitoring events. Table 1 (see attached) has been revised to reflect this change. The text will be modified accordingly.

USEPA/DNREC Comment 8. Approaches and Methodologies, Well Installation/ Development: The Work Plan states: “The wells will be …. installed through 8-inch diameter, steel isolation casing grouted into the UPCU (competent clay) which divides, where present, the Columbia Aquifer from the UPA. If the UPCU is absent, the isolation casing will be grouted into a lower conductivity portion of the UPCUTZ. The placement of the well screens will be determined in the field, based on: 1) observed volatile organic impact based on organic vapor (i.e., PID) readings (although unlikely) and/or 2) visual evidence of impacts. If there is no evidence of either, then the screen interval will be set across the portion of the UPA (either upper sand or lower sand) with the coarsest materials.” It is unclear how deep the wells will be drilled. The objective for the targeted screen interval is also unclear. Contamination is typically found in the less transmissive zones, rather than the most transmissive zone.

ACPS and NCC Response to USEPA/DNREC Comment 8:
The primary objective of this study is to determine whether contaminants are migrating from the Western Lobe of the ACL at a rate that will ultimately impact AWC’s Llangollen Wellfield. Contaminants have the potential to migrate farthest and fastest through transmissive zones, not through low permeability zones. Because we are looking for transport pathways, at a distance from the landfill, the high permeability zones should be the targeted zones for these wells.

USEPA/DNREC Comment 9. Approaches and Methodologies, Surveying: The first paragraph discusses survey discrepancies that exist between the ACL and the DS&G Sites. A table should be added to the Work Plan identifying the discrepancies to be assessed/corrected.

ACPS and NCC Response to USEPA/DNREC Comment 9:
As requested, a table (Table 3) has been prepared indicating the available survey information from the wells listed on Table 1 and identifying the survey discrepancies. This table is attached and will be included in the revised Work Plan.

USEPA/DNREC *Comment 10*. Approaches and Methodologies, PFAS Source Evaluation: It is stated that “an important consideration in the evaluation of PFAS in the gas vent liquids is that the analytical method for PFAS is a drinking water method not intended for use on other matrices such as leachate or wastewater.” This statement is correct. However, commercial laboratories have analyzed non-drinking water matrices, including leachate, using Method 537, Revision 1.1 with modifications. Potential matrix interference can be mitigated by providing the laboratory with historical Site data, e.g., analytical results for the aqueous samples collected from the gas vents from 2004 to 2007. This information can be used by the laboratory to identify corrective measures or alternative techniques to reduce matrix interference during analysis of aqueous samples collected from gas vents. These samples could also be analyzed using the direct-inject method described in EPA Region 5’s draft SOP (attached) for PFAS as an alternative to, or in addition to, analysis by Method 537. Region 5 has analyzed leachate samples from Superfund sites in Minnesota and Michigan using this method.

<u>ACPS and NCC Response to USEPA/DNREC Comment 10</u>:
Golder provided this comment and request to Eurofins of Lancaster, Pennsylvania and discussed the comment and request with them. Eurofins indicated that use of the isotope dilution method, which Eurofins uses for PFAS analysis (Method 537, Revision 1.1 Modified), is the best to use to avoid matrix interferences. As for use of the direct-injection method in development and use by USEPA Region 5, Eurofins indicated that they are familiar with the technology and have spoken with Larry Zintack (EPA Region 5) regarding use of and results from the direct injection method. It is Eurofins' opinion that the direct injection method does not account for ion suppression; therefore, use of the method has the potential to produce biased low results for PFAS due to matrix interferences.

<u>USEPA/DNREC Comment 11.</u> Approaches and Methodologies, PFAS Source Evaluation: It is recommended that Artesian's Midvale wells to the north and upgradient of ACL be included in this sampling effort.

<u>ACPS and NCC Response to USEPA/DNREC Comment 11</u>:
As recommended, Ms. Susanna Mays (Administrator for ACPS) contacted AWC regarding this request. AWC currently samples and analyzes these wells annually in September for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Ms. Mays discussed expanding the PFAS analyte list with AWC such that the PFAS analyte list is consistent with the analyte list proposed for the ACL and DS&G Sites for AWC's September 2018 sampling event. Ms. Mays is awaiting a response from AWC about inclusion of these additional analyses.

Due to the influence of various well fields on groundwater flow direction in the region (DNREC-SIRS, 2017), has DNREC or the USEPA prepared a groundwater flow model and/or maps for the region that encompasses AWC's Midvale wells and demonstrates the groundwater flow direction(s) to and from AWC's Midvale wells? If so, please provide this information to the ACPS and NCC.

<u>USEPA/DNREC Comment 12.</u> Reporting: Please specify that PFAS results will be provided to EPA and DNREC in the EQuIS EDD format.

<u>ACPS and NCC Response to USEPA/DNREC Comment 12</u>:
The Work Plan and the SAP will be revised to indicate that PFAS results will be provided to the USEPA and DNREC as an electronic database deliverable (EDD) in the EQUIS format.

<u>USEPA/DNREC Comment 13.</u> Table 1: Is monitoring well 38N the same well as 38 depicted on Figure 2? Please clarify.

<u>ACPS and NCC Response to USEPA/DNREC Comment 13</u>:
Yes. The well designation has been changed to 38N on Figure 2. The attached Figure 2 will be included in the revised Work Plan.

<u>USEPA/DNREC Comment 14.</u> Table 1: A note should be included in the table to indicate when, with respect to sample collection (before or after), water elevations will be measured for each quarterly monitoring event.

<u>ACPS and NCC Response to USEPA/DNREC Comment 14</u>:
As requested, a note has been added to Table 1 (see attached revised Table 1) indicating that water elevations will be measured after sample collection for all events (see also Response to USEPA/DNREC Comment 19). The attached Table 1 will be included in the revised Work Plan.

USEPA/DNREC Comment 15. Figures 2 and 4: The gas vents are represented by an assortment of circles, ovals, rings and squares. The same symbol should be used to represent all of the gas vents and the symbol should match the corresponding symbol in the legend.

ACPS and NCC Response to USEPA/DNREC Comment 15:
As requested, Figures 2 and 4 have been revised; Figure 4 has been re-designated as Figure 6. The attached Figures 2 and 6 will be included in the revised Work Plan.

Attachment 4 of the Work Plan – Sampling and Analysis Plan

USEPA/DNREC Comment 16. Section 4.2.1, Western Lobe: This section states that wells with long screens will be purged and sampled from two locations to assess potential differences in concentrations across the upper and lower sand units. Regardless of where the pump is placed, the sample will be a flow-weighted average of the screen interval. It is not recommended that long screened wells be used to monitor a contaminant plume and they should not be sampled using low-flow techniques. Low-flow sampling protocols specifically state that the screen should be short (10 feet or less). It is recommended that the well network be carefully evaluated to determine where, if anywhere, low-flow sampling is appropriate and if the replacement of long-screened wells with well clusters would be appropriate. Wells screened across both the upper and lower sands of the UPA would be candidates for replacement.

ACPS and NCC Response to USEPA/DNREC Comment 16:
It is agreed that a flow-weighted average sample would be more representative of the interval across which the well is screened, and it is understood that low-flow sampling protocols state that the protocol should be used for wells with a 10-foot or less screened interval. The well network was evaluated during preparation of the Work Plan. Table 2 provides the screen lengths for the wells included in the Work Plan. See the Response to the USEPA/DNREC Comment 4 for additional information.

Recognizing the long-screen wells were installed to monitor the entire aquifer thickness, but that plume thicknesses can be much less than the aquifer thickness, collecting samples from two different depths within the long-well screen will aid in assessing whether a portion of the existing well screen intercepts the contaminant flow path, and if so, which portion(s) - the UPA upper sand, lower sand or both. The data from "profiling" the screen interval over the first year of monitoring (three quarterly monitoring events) will be used to determine if the long-screen wells are actually within the plume and require a more refined screen interval or if or a well pair would be more appropriately placed in another area.

See the Responses to the USEPA/DNREC Comments 17 and 24 for additional discussion regarding flow-weighted average sampling and well yields. The text in SAP Section 4.2.1 has not been revised as it relates to this comment.

USEPA/DNREC Comment 17. Section 4.2.1, Western Lobe: If wells MW-38N and MW-49N are to be sampled, the pumping rate during purging should be slightly less than the yield of the well. After one well volume has been removed, stabilization of field parameters should be monitored while continuing to purge up to three well volumes. One flow-weighted average sample should be collected from each of these wells.

<u>ACPS and NCC Response to USEPA/DNREC Comment 17</u>:
See also the Responses to USEPA/DNREC Comments 16 and 24. Well yield information is available for a few wells (see Attachment 6). The available information indicates that the well yields are in the tens of gallons per minute. As explained in the Response to the USEPA/DNREC Comments 16, the purpose of the proposed low-flow purging and sampling approach is to develop a profile at these long-screen well locations to determine if the long-screen wells are actually within the plume and require a more refined screen interval <u>or</u> if or a well pair would be more appropriately placed in another area.

The proposed low-flow purging and sampling approach presented in the Work Plan is applicable for collecting samples from discrete intervals to evaluate the contaminant plume elevation within the wells. Using a pumping rate slightly less than the yield of the well (which is tens of gallons per minute) would not provide discrete interval information, and could create turbulence in the well, entrain particulates in the samples, and strip VOCs from the samples. As stated in "Recommended Procedure for Low-flow Purging and Sampling of Groundwater Monitoring Wells, Bulletin No. QAD023" dated October 15, 1997, "[r]esearch conducted by Puls et al. (1992), Puls and Powell (1992), and Powell and Puls (1993) has shown that high-volume purging and sampling cause significant turbidity and suspended particulate artifacts that can result in biased-high metals results. Additionally, purging can cause pressure changes and bailing can cause aeration that can strip VOCs from the sample (Pennino, 1988). The use of low-flow pumping devices (preferably dedicated) for purging and sampling minimizes both the disturbance of water in well casing and the potential for mobilization of colloidal material (Barcelona et al., 1994). Low-flow purging with maintenance of water level in the well and stabilization of indicator parameters (especially turbidity) allows collection of groundwater samples that are more representative of conditions without filtering (U.S. EPA, 1993; Backhus et al., 1993)." (USEPA, 1997)

The text in SAP Section 4.2.1 has not been revised as it relates to this comment.

<u>USEPA/DNREC Comment 18.</u> Section 4.2.1, Western Lobe: This section states that all analyses will be performed during each sampling quarter which is inconsistent with the Work Plan. Please review and revise as necessary.

<u>ACPS and NCC Response to USEPA/DNREC Comment 18</u>:
The sentence in SAP Section 4.2.1 describing the frequency has been revised to state the following: "After installation and development of the new wells, groundwater from the nine wells will be sampled quarterly, as outlined in this SAP, for iron, manganese, cobalt and VOCs (including 1,2-DCA). Major anions and cations will be monitored semi-annually coincident with the semi-annual monitoring events for the Site."

<u>USEPA/DNREC Comment 19</u>. Section 4.2.1, Western Lobe: The water level measurement activity is not detailed in the text and Table 1 states only that a complete round of water levels will be measured synoptically at all wells. The procedure and schedule for synoptic water level measurements should be specified.

<u>ACPS and NCC Response to USEPA/DNREC Comment 19</u>:
The following text has been added/revised in SAP Section 4.2.1 to address this comment. "Section 4.3.3.1 describes the water level monitoring procedure and schedule for the wells listed in Table 1. Section 4.3.3.2 describes the low-flow purging and sampling methodology for the wells listed on Table 1."

In the revised SAP, Section 4.3.3.1 will address the Water Level Measurement Procedures and subsequent sections will be renumbered. The following text is included in SAP Section 4.3.3.1: "Depth to water measurements should be taken from all wells indicated on Table 1 Proposed Monitoring Program, within a time period (not to exceed 48 hours) that is not interrupted by severe changes in barometric pressure or by precipitation events. The synoptic water level measurements will be performed AFTER collection of groundwater samples due to the inclusion of PFAS as an analyte at the Site.

Depth to water will be measured in each monitoring well to the nearest 0.01-foot using an electronic depth-indicating sounder. All groundwater measurements will be made in reference to a control point of known elevation at the top of the well casing. If a total depth measurement is necessary, to confirm well construction information for example, it will be taken after any scheduled sample collection to minimize potential cross-contamination and disturbance to sediments, which may have accumulated in the bottom of the well."

USEPA/DNREC Comment 20. Section 4.3, Sampling Methods: The Work Plan should note the survey(s) to be conducted to avoid encountering subsurface utilities at the drilling locations.

ACPS and NCC Response to USEPA/DNREC Comment 20:
The following text has been added to SAP Section 4.3.1 to address this comment: "Prior to any ground disturbance or at the proposed drilling locations, the following activities will be performed for the drilling locations to avoid subsurface utilities:

1. *The drilling locations will be pre-marked out and Miss Utility will be contacted to mark out utilities on public properties;*
2. *Available Site drawings and public utility information will be reviewed to locate utilities on private and public properties; and*
3. *Private utility locating service will be contracted to perform ground-penetrating radar (GPR) and/or electromagnetic (EM) surveys."*

USEPA/DNREC Comment 21. Section 4.3.1, Soil Boring Advancement: Section 4.3.2.2 of the Work Plan specifies use of PFAS-compliant materials for well development. This section should specify that all materials, drill fluids and tooling lubricants used during drilling and well installation will be PFAS compliant.

ACPS and NCC Response to USEPA/DNREC Comment 21:
PFAS-compliant materials (as certified by the manufacturer), including drilling fluids and tooling lubricants, will be used during drilling activities. If information related to PFAS compliance of a material is not available, the driller may be asked to change materials used, if possible, or a material sample or rinse sample of equipment (if applicable) will be collected for analysis of PFAS. The following text has been added to revised SAP Section 4.3.1: "PFAS-compliant materials (as certified by the manufacturer), including drilling fluids and tooling lubricants, will be used during drilling activities. If information related to PFAS compliance of a material is not available, the driller may be asked to change materials used, if possible, or a material sample or rinse sample of equipment (if applicable) will be collected for analysis of PFAS."

USEPA/DNREC Comment 22. Section 4.3.2.1, Monitoring Wells: This section of the SAP describes well installation procedures for the upper and lower sand wells. As noted in the Work Plan, the dividing clay layer that separates the upper and lower sand can be intermittent or thin in areas. The alternate well installation procedures to be used if the dividing clay layer is not encountered during drilling should be described. The SAP should state that EPA will be consulted prior to well construction.

ACPS and NCC Response to USEPA/DNREC Comment 22:
The following presents the revised text within SAP Section 4.3.2.1 regarding well installation procedures:

> *An 8-inch to 12-inch diameter (dependent on anticipated screened lithologic unit), threaded, permanent [MT1] steel isolation casing will be advanced during soil boring advancement. Once the UPCU (clay layer) is encountered, the isolation casing will be advanced two feet into the clay layer. The isolation casing will then be pressure tremie-grouted to the ground surface. Grout will be allowed to set for a minimum of 24 hours before resuming drilling. If the UPCU is absent, the isolation casing will be grouted into a finer-grained (lower conductivity) interval of the UPCUTZ. If the UPCU and UPCUTZ are not observed during drilling, the isolation casing will be grouted approximately two feet into the top of the UPA upper sand as observed in the field based on lithologic changes in recovered soil cores during drilling.*
>
> *Upon curing of the grout, the boring will be advanced to the Upper Potomac Dividing Clay (UPDC). Once the UPDC (clay layer) is encountered, an 8-inch to 10-inch diameter, threaded, temporary steel isolation casing will be advanced two feet into the clay layer. The isolation casing will then be pressure tremie-grouted to the ground surface. During grouting, the isolation casing will be recovered at a rate that ensures that the base of the casing remains below the tremied-grout surface. Grout will be allowed to set for a minimum of 24 hours before resuming drilling. If the UPDC is not encountered (i.e., no lithologic separation between the UPA upper and lower sand is observed), then there is no need first isolation casing between the UPA upper sand and UPA lower sand units for a UPA lower sand well, and the boring will be advanced until the top of the Middle Potomac Confining Unit (MPCU) is encountered."*
>
> *The following presents the text added to SAP Section 4.3.2.1 regarding consultation with the USEPA prior to well construction: "Prior to well construction within the advanced borehole, the USEPA will be provided with a draft annotated boring log indicating the proposed well screen interval for their review and approval of the proposed screened interval. Due to concerns regarding limiting resident's access to their property during boring advancement and well installation, a quick response/approval (within two business hours) from the USEPA will be necessary.*

USEPA/DNREC Comment 23. Section 4.3.3, Groundwater Monitoring Well Sampling Procedures, and SOP-2: DNREC's Site Investigation and Restoration Section has been working on developing field sampling protocols for PFAS to help minimize possible sample contamination. They have been using the attached EPA NASA PFCs SOP. MassDEP [Massachusetts Department of Environmental Protection] and NHDES [New Hampshire Department of Environmental Services] have also developed detailed PFAS collection guidance which may be helpful to review. Also attached for consideration is DNREC's Site Inspection Work Plan from May 2017 which includes PFAS sampling for the nearby New Castle Public Wells Groundwater Plume Site.

ACPS and NCC Response to USEPA/DNREC Comment 23:
Golder has re-reviewed the protocol prepared by Tetra Tech for the USEPA NASA (dated April 2016; Tetra Tech, 2016), the draft MassDEP protocol (dated January 2017; MassDEP, 2017) and the NHDES protocol (dated November 2016; NHDES, 2016). Golder's SOPs provided in the

PFAS Work Plan included the items in the protocols developed by Tetra Tech, the NHDES, and the MassDEP, and our protocols are generally more stringent. A few examples where Golder's protocols are more stringent include the following:

- *Deconning (usage of methanol in addition to DI and Alconox)*
- *Specific instructions on when to change nitrile gloves (other protocols generally say "change gloves often")*
- *Instructions on field clothing laundering before use*
- *Covering vehicle seats with cotton sheets to prevent contact with vehicle seat fabric*
- *No usage of sunscreen or bug spray*
- *In order to consume food or beverage we must move to a distance of 35+ ft away, preferably downwind*

As such and as indicated in responses to the USEPA Comments 32 and 33, and OASQA Comment 12 we have not observed issues associated with PFAS cross-contamination and/or the ubiquitous use of PFAS in field, rinsate or equipment blanks that we have collected and analyzed at other PFAS sites. As such, no revisions to SAP Section 4.3.3 and/or SOP-2 are proposed as it relates to these comments.

USEPA/DNREC Comment 24. Section 4.3.3.2, Low-Flow Groundwater Sampling Procedures: As noted above, low-flow sampling may not be appropriate for all wells. Please submit the information requested above regarding stratigraphy and lithology and, also, well construction and well yield information for existing well locations.

ACPS and NCC Response to USEPA/DNREC Comment 24:
See also responses to the USEPA/DNREC Comments 5, 16, 17 and 26. As requested, the screened interval and aquifer unit screened for the monitoring wells listed in Table 1 have been compiled and presented in Table 2, which is attached and will be included in the revised Work Plan. Available boring logs for the wells listed on Table 2 are attached to this response and will be included as Attachment 6 of the revised Work Plan. Well yield information is available for a few wells (see Attachment 6). The text in SAP Section 4.3.3.2 has not been revised as it relates to this comment.

USEPA/DNREC Comment 25. Section 4.3.3.2, Low-Flow Groundwater Sampling Procedures, first paragraph: The SAP states that samples will be collected using Teflon-lined tubing (with the exception of the PFAS monitoring event). Section 4.3.2.2 of the SAP notes that HDPE tubing will be used during well development. It is recommended that any sampling events occurring before the PFAS sampling also be performed using HDPE tubing.

ACPS and NCC Response to USEPA/DNREC Comment 25:
HDPE tubing will be used for all sampling events. SAP Section 4.3.3.2 will be revised to state the following: "Prior to sampling, each monitoring well will be purged using a dedicated or decontaminated 2-inch submersible pump (Grundfos RediFlo, Proactive or equivalent) and high-density polyethylene (HDPE) tubing dedicated to each well."

USEPA/DNREC Comment 26. Section 4.3.3.2, Low-Flow Groundwater Sampling Procedures: The SAP states that during purging, field parameters will be monitored until the parameters stabilize based on three consecutive readings within specified ranges. Measurement of field parameters should not be made until at least one well volume, plus the volume of the sampling apparatus and tubing, has been removed.

<u>ACPS and NCC Response to USEPA/DNREC Comment 26</u>:

The USEPA's low flow purging and sampling guidance documents and other sampling protocols were reviewed and references to removal of one well volume in addition to removal of the sampling apparatus and tubing could not be found. The ACPS and NCC are not familiar with guidance indicating one well volume should be purged as well as the volume of the sampling apparatus and tubing as part of the low-flow sampling protocol. As stated in Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers by Yeskis and Zavala dated May 2002 (EPA 542-S02-001), "[d]uring the purging, a minimum of one tubing volume (including the volume of water in the pump and flow cell) must be purged prior to recording the water-quality indicator parameters." As such, no revisions to the SAP Section 4.3.3.2 are proposed.

<u>USEPA/DNREC Comment 27.</u> Section 4.3.3.2, Low-Flow Groundwater Sampling Procedures and Section 4.3.3.3, Volume Average Purging Using Bailers: The procedure for filling VOC vials states, "If air bubbles are discovered, additional groundwater will be added to the vial until the bubbles are removed." If air bubbles are discovered during sampling, the sample vial should be discarded and a new sample should be collected, filling the entire bottle.

<u>ACPS and NCC Response to USEPA/DNREC Comment 27</u>:

The ACPS and NCC are not familiar with this requirement and adding additional small quantities to VOC vials to remove minor air bubbles is standard practice. However, this requested change is minor; therefore, it will be incorporated into the revised SAP Section 4.3.3.2 as the following text: "If air bubbles are discovered, the vial will be discarded and a new vial with be filled and checked for bubbles. The above procedure will continue until a minimum of two VOC vials per sample location are collected."

<u>USEPA/DNREC Comment 28.</u> Section 4.3.3.2, Low-Flow Groundwater Sampling Procedures: The SAP states that "filtered (dissolved) metals samples will be collected by forcing groundwater through a 0.45-micron filter attached to the end of the discharge tubing." The samples should only be field filtered using an in-line 0.45-micron filter. However, the rationale for filtering the samples is unclear. The premise underlying the use of low-flow sampling is that particulates are not entrained and, therefore, there is no need to filter the sample for inorganic analysis. Only total metals should be taken for analysis when using low-flow sampling techniques.

<u>ACPS and NCC Response to USEPA/DNREC Comment 28</u>:

While it is anticipated that wells will have a turbidity less than 10 NTUs (low-flow guidance allows for dissolved metals analysis if turbidity is greater than 10 NTUs), it is possible that entrained particles (e.g., metal flakes due to corrosion of old steel extraction well casings or other particles) might be collected in the groundwater samples for total metals samples. Therefore, total as well as dissolved metals samples will be collected and analyzed. SAP Section 4.3.3.2 has been revised to state: "Consistent with low-flow guidance, Site practices over more than the last 10 years and to maintain a consistent data set, metals samples will be collected for analysis of total and dissolved metals. The filtered (dissolved) metals samples will be collected using an inline 0.45-micron filter attached to the end of the discharge tubing without a flow-through cell in-place."

<u>USEPA/DNREC Comment 29.</u> Section 4.3.3.3, Volume Average Purging Using Bailers: Bailers should not be used to collect samples for analysis of VOCs and inorganics.

<u>ACPS and NCC Response to USEPA/DNREC Comment 29</u>:
The depths to groundwater and well diameters have been reviewed, and it has been determined that bailers will not be needed to sample monitoring wells. However, due to the viscosity of the leachate in the gas vents, bailers will be used to purge and collect gas vent samples for PFAS analysis. Gas vent samples will not be collected for VOCs and/or inorganics analysis. As such the text in SAP Section 4.3.3.3 has been revised to remove reference to VOC and metals sample collection using bailers.

<u>USEPA/DNREC Comment 30.</u> Section 4.3.3.3, Volume Average Purging Using Bailers: The SAP states, "If the well runs dry during purging, the pump will remain within screened interval and the groundwater in the well will be allowed to recharge to approximately 80 percent of its initial water level measurement prior to the restart of purging. This process will proceed until the 3 to 5 well volume removal criteria is accomplished. Water quality parameters will be recorded in the same manner as described above." Under no circumstances should a well be purged to dryness. For wells which recover slowly, the water level should be drawn down and allowed to recover three times. As soon as the well has recovered sufficiently to sample, samples should be collected immediately.

<u>ACPS and NCC Response to USEPA/DNREC Comment 30</u>:
See response to the USEPA/DNREC Comment 29 above. The depths to groundwater and well diameters have been reviewed (see attached Table 2), and it has been determined that bailers will not be needed to sample monitoring wells; however, due to the viscosity of the leachate in the gas vents, bailers will be used to purge and collect gas vent samples for PFAS analysis. As such the text in SAP Section 4.3.3.3 has been revised to remove reference to purging to dryness, and the text has been revised to state as follows:

"Due to the viscosity of the leachate in the gas vents, bailers will be used to purge and collect gas vent samples for PFAS analysis. Past experience with purging and collection of leachate samples from these gas vents indicates that due to the very slow recharge of leachate into the gas vents, only one to three well volumes can be purged within a 24-hour period. Therefore, the standard protocols for volume average purging using bailers was modified for purging and collecting samples from the gas vents.

The gas vents will be purged using a dedicated or disposable, bottom-filling, non-Teflon bailer. Nylon well rope will be securely tied to the new or dedicated bailer. The bailer will be gently lowered into the water column in order to minimize disturbance. Once the bailer fills, it will be slowly pulled up. Field parameter readings (pH, DO, conductivity, temperature, ORP, and turbidity) will be collected from the initial bailer of water, and following removal of each well volume. All measurements will be recorded on the Volume Average Groundwater Purge/Sample Field Information Form (Attachment C) and/or in field notebooks. This practice will be repeated until one of the following occurs:

1. *At least 3 (minimum if field parameters meet stabilization criteria), but no more than 5 standing water volumes have been evacuated.*

2. *Gas vent is purged "dry" (i.e., less than approximately 6 inches of leachate remains in the gas vent). If a gas vent is purged "dry", then it will be given up to 24 hours to recharge before samples are collected.*

The sampling locations were originally constructed for gas venting; therefore, the static water/leachate level within the vents may be at, above or below the top of the screen, and in some locations minimal, if any, leachate is present within the gas vent. The samples will be collected as soon as there is a sufficient recharge volume to fill the sample bottles. The bailer will be slowly lowered down the well into the top of the water column such that unnecessary disturbance to the sample does not take place."

USEPA/DNREC Comment 31. Section 4.3.3.3, Volume Average Purging Using Bailers: The SAP states the following: "The filtered metals sample will be collected by attaching the filter to the end of the bailer and allowing the sample to gravity feed from the bailer into the sample bottle.

Alternatively, the sample to be filtered will be placed in a FF-8200 transfer vessel (or equivalent) and filtered prior to placement in the sample bottle. Each sample collected for filtered metals analysis will be poured from the bailer into a transfer vessel and forced through a 0.45-micron filter prior to placement into the sample bottle. The sample will be forced through the filter using a hand pump or pressurized nitrogen." Under no conditions should the filtering procedures described here occur. Please see comments regarding filtering, above.

ACPS and NCC Response to USEPA/DNREC Comment 31:
See Response to the USEPA/DNREC Comment 29 above. The depths to groundwater and well diameters have been reviewed (see attached Table 2), and it has been determined that bailers will not be needed to sample monitoring wells; however, due to the viscosity of the leachate in the gas vents, bailers will be used to purge and collect gas vent samples for PFAS analysis. As such the text in SAP Section 4.3.3.3 regarding filtered metals samples from bailers has been removed.

USEPA/DNREC Comment 32. Section 4.4.1, PFAS Decontamination: Deionized water and methanol used for PFAS decontamination must be certified to be PFAS free. The use of Ziploc® storage bags to store equipment where the equipment comes in direct contact with the bag has the potential to transfer PFAS to sampling equipment. It would be impossible to know if this is an issue without first analyzing the Ziploc® bags.

ACPS and NCC Response to USEPA/DNREC Comment 32:
A sample of the DI water and the methanol to be used for decontamination will be collected and analyzed to certify it is PFAS-free prior to use in the field. Due to the volume of DI water and methanol needed for decontamination, after analysis of the DI water and methanol indicates they are PFAS-free, the same source of DI water and methanol will be used for the entire sampling event. If DI water and/or methanol sources are changed during or between events, then additional samples of the DI water and/or methanol used will be collected and analyzed to certify it is PFAS-free. The text in SAP Section 4.4.1 has been revised to indicate that the DI water and methanol will be certified PFAS-free.

Golder has not observed transfer of PFAS from Ziploc bags to equipment. However, to alleviate this concern, Ziploc bags will not be used. Section 4.4.1 has been revised to remove reference to storage of decontaminated equipment "in a clean Ziploc storage bag until needed for sampling."

<u>USEPA/DNREC Comment 33</u>. Section 4.4.4, Groundwater Sampling Equipment: Section 4.4.1 of the SAP includes a separate decontamination procedure for PFAS equipment. Procedures for decontaminating non-dedicated submersible pumps for PFAS sampling should be included in this section. Deionized water and other solvents used for decontamination need to be certified as PFAS free.

<u>ACPS and NCC Response to USEPA/DNREC Comment 33</u>:
As requested, the PFAS decontamination procedures were added to SAP Section 4.4.4 to address procedures for decontaminating non-dedicated submersible pumps for PFAS sampling as follows:

> *"..., decontamination fluids will be pumped from buckets through the pump as follows:*
>
> 1. *Flush the pump with potable water to remove any sediment that may be trapped in the pump;*
> 2. *Flush the pump with a weak, non-phosphate detergent solution (approximately 5 gallons);*
> 3. *Flush the pump with tap water to remove all the detergent solution. Generous amounts of tap water (at least 3 pump volumes) should be used to ensure that detergent and any sediment that may be trapped in the pump does not remain in the pump;*
> 4. *Flush the pump with deionized or distilled water (during PFAS-sampling events, use certified PFAS-free DI water);*
> 5. *Flush the pump with isopropyl alcohol (during PFAS-sampling events, use certified PFAS-free methanol). Use sparingly to minimize presence of this decontamination fluid in the samples; and*
> 6. *Flush the pump with analyte-free water (during PFAS-sampling events, use certified PFAS-free DI water). Generous amounts of water (at least three pump volumes) should be used to remove as much of the isopropyl alcohol (or methanol) as practical."*

See Response to the USEPA/DNREC Comment 32 regarding certification of DI water and methanol as PFAS-free prior to monitoring events. The text in SAP Section 4.4.4 has been revised to indicate that the DI water and methanol will be certified PFAS-free.

<u>USEPA/DNREC Comment 34.</u> Section 4.8, Quality Control, second paragraph: As discussed in Section 3.2 of SOP-3, deionized water blank(s) should be collected during PFAS sampling. This sample type and description should be added to Section 4.8 of the SAP and its subsections.

<u>ACPS and NCC Response to USEPA/DNREC Comment 34</u>:
As requested, SAP Section 4.8.4 Field Blanks has been added to the revised SAP to address this comments. The section states:

> *"As described in SOP-3, field personnel shall submit of one field blank per day of sampling. Field blanks shall consist of PFAS-free water containerized in an HDPE sample container filled at the laboratory prior to beginning the field program. Field blank sample containers shall be opened during the collection of a sample and the laboratory-supplied PFAS-free water contained therein shall be poured directly into a laboratory-supplied HDPE sample container, then resealed. Field blank container lids shall remain in the hand of field personnel until replaced on the sample container. Sample container labels shall be completed as described above."*

USEPA/DNREC Comment 35. **Section 4.10.2, Photovac Microtip Photoionization Detector:** 1,2-dichlor[o]ethane has an ionization potential of 11.04 eV. The field crew should us[e] an 11.7-eV lamp during soil screening to achieve the broadest VOC detection range.

ACPS and NCC Response to USEPA/DNREC Comment 35:
The text in SAP Section 4.10.2 has been modified to reflect this change as follows: "An 11.7 eV lamp will be used on the PID as gross screen for VOCs since the primary VOCs at the Site have good responses to the 11.7 eV lamp."

OASQA Comments with ACPS and NCC Responses

OASQA Comment 1. A distribution list should be included in the SAP. A distribution list includes all individuals and their organizations who will receive copies of the approved QAPP and any subsequent revisions.

ACPS and NCC Response to OASQA Comment 1:
As requested, a distribution list will be included in the revised SAP that includes all individuals and their organizations who will receive copies of the approved QAPP and any subsequent revisions.

OASQA Comment 2. A project organization chart in this document is very short. It should go into detail and highlight individuals or organizations who are participating in the project with their responsibilities. (e.g., data users, decision-makers, project QA manager, subcontractors, etc. should be included). In addition, it should include EPA's role and other stakeholders/decision makers.

ACPS and NCC Response to OASQA Comment 2:
As requested, a more detailed project organization chart will be included in the revised SAP.

OASQA Comment 3. Individuals responsible for sampling operations and sampling QC should be identified. In addition, a third party is recommended for data validation which should be identified in the SAP/QAPP.

ACPS and NCC Response to OASQA Comment 3:
As requested, individuals responsible for sampling operations and sampling QC will be identified in the revised SAP. Options for data validation are being reviewed at this time. The data validation contractor will be identified in the SAP/QAPP.

OASQA Comment 4. Potential migratory pathways should be included in the SAP/QAPP. If the SAP/QAPP does not have the required information and refers to a different document it should be included with the SAP/QAPP.

ACPS and NCC Response to OASQA Comment 4:
In response to this request, the following text was added to Section 2.1 of the revised SAP: "The potential migration pathways are presented as part of the Conceptual Site Model (CSM) in the Work Plan."

To address potential migration pathways, the following text has been included as a new section (Potential Migration Pathways) in the revised Work Plan CSM:

> *"In the area between the ACL and AWC's Llangollen wellfield, the COCs migrate with groundwater within the UPA based on the hydraulic gradient and resulting groundwater flow direction. The overall flow direction in the UPA is to the south toward AWC's Llangollen wellfield. However, the groundwater flow direction can vary from southwest to southeast depending on which wells AWC is operating and their withdrawal rates.*
>
> *COCs follow an overall downward flow path starting in the Columbia Aquifer at the ACL Site, then migrating downward with distance from the landfill into the UPA upper sand, and eventually into the UPA lower sand. It is anticipated that COCs migrate into the UPA lower sand from the UPA upper sand due to operation by AWC at its Llangollen wellfield and potential discontinuous portions of the UPDC in the area."*

OASQA Comment 5. The DQOs for this project do not clearly identify the threshold or action levels. The DQO process is a seven-step process that provides guidance on developing data quality criteria and performance specifications for decision making. Please refer to the EPA's (QA/G-4) guidance document. DQOs should include decision statements using "If…then" to exemplify the actions taken if thresholds are exceeded. DQOs should elaborate on the specific analytical method, method's applicability and limitation for the data to meet. The SAP/QAPP should include a decision statement derived from the produced analytical data. The statement should be more precise, e.g. "If no detections are found, then no further action is needed".

ACPS and NCC Response to OASQA Comment 5:
In response to this comment and OASQA Comments 6 and 7, see attached SAP Tables 1 and 2 (these tables will be included in the revised Work Plan as SAP Tables 1 and 2 and subsequent tables will be renumbered). In addition, the following text has been added to revised SAP Section 2.2: "The Data Quality Objectives (DQOs) for the additional investigation activities described in the revised Work Plan are summarized in Table 1 and the Decision Thresholds/Action Levels are presented in Table 2. The DQO process as it relates to the Measurement Performance Criteria is described in Section 3."

OASQA Comment 6. DQO must include data usability, data acceptance criteria, project decisions and sampling conditions. For example: what actions are contemplated if analytical results are greater or lesser than project decision thresholds? What will be the next step or action?

ACPS and NCC Response to OASQA Comment 6:
See Response to OASQA Comment 5.

OASQA Comment 7. The screening values must be specified and stated throughout the document. Emphasis needs to be placed on the "decision threshold" or action levels which will determine the applicability of the proposed analytical methods and their ability to achieve the necessary sensitivity for this sampling event. As part of the DQO process, the sampling event should have its sampling goals delineated. This will lead to having decision thresholds and resulting actions clearly described in the document as "If…Then" statements. The QAPP should define the potential consequences of decision errors (i.e., false positive error or false negative error) near the action level.

ACPS and NCC Response to OASQA Comment 7:
See Response to OASQA Comment 5. The screening values are presented on the SAP tables.

OASQA Comment 8. A project timetable including all deliverables with implementation and audit schedules should be provided in the QAPP. A table is recommended for this information.

ACPS and NCC Response to OASQA Comment 8:
In response to this comment, a project timetable is difficult to prepare given the review and approvals needed from the USEPA; however, a general project timetable is provided in the "Schedule" section of the Work Plan. The Schedule section will be updated in the revised Work Plan.

Section 5.1 of the SAP references audits. As indicated in the SAP, there are no plans for field/sampling audits and/or laboratory audits unless the USEPA deems an external laboratory audit is necessary. As requested, a table summarizing the project timetable for implementation, deliverables and potential audit schedules, if necessary, will be included in the revised Work Plan.

OASQA Comment 9. Whenever a mass spectral analysis is requested using any SW-846 Methods, such as 8260B Volatiles, then it is important to request the testing laboratory to submit a Tentatively Identified Compound (TIC) list with each analysis. The TIC list can help identify organic unknowns at the site that fall outside the Target Compound List.

ACPS and NCC Response to OASQA Comment 9:
As part of the monitoring program for the adjacent DS&G Site, many of the wells downgradient and in the vicinity of the ACL Site are monitored and TICs are reported by the testing laboratory. In addition, the TICs for the DS&G Site are evaluated approximately every two years and the evaluation is submitted to the USEPA for review (see attached "Review of Tentatively Identified Compounds in Groundwater" for the DS&G Site dated December 21, 2016; Golder, 2016). Based on the last review of TICs in groundwater for the DS&G Site, as performed on semi-annual groundwater data for the 2015 and 2016 monitoring events, very few TICs are reported for the "NCC Monitoring Wells" (wells downgradient of the ACL) and none of the TICs were identified frequently. Therefore, based on available TIC data collected from the adjacent DS&G Site, there does not appear to be a need to request that the testing laboratory submit a TIC list with each VOC analysis for the ACL Site. As such, this change has not been made to the SAP.

OASQA Comment 10. The frequency and distribution of reports for results of periodic data quality assessments should be included in the SAP/QAPP. The frequency and distribution of reports for changes in the SAP/QAPP should be included. The QAPP should state revisions/updates (if applicable) which can be every 3-5 years.

ACPS and NCC Response to OASQA Comment 10:
In response to this comment, the following text has been added to the revised SAP in Section 5.1.5: "Data quality assessments will be performed as part of the semi-annual monitoring reports for the Site. These assessments will be included in and distributed to the parties that receive the semi-annual monitoring reports, including but not limited to the USEPA, DNREC, NCC and the ACPS."

In response to this comment, the following text has been added to and updated in the revised SAP in Section 2.5: "This SAP includes the revision number and date, and will be updated as needed based on changes in Site conditions and/or applicable regulatory requirements. The *revised SAP will be distributed to the USEPA, DNREC, NCC and the ACPS. The QAPP will include revisions/updates (if applicable) every 3 to 5 years."*

OASQA Comment 11. OASQA is not recommending accepting any modifications to EPA Method 537. At this time, available information indicates the use of modified EPA Method 537 can, among other things, provide results that artificially suppress or enhance analyte concentrations reported as the result of using the modified analysis. This ultimately can result in the rejection of sample data. While EPA Method 537 is written for drinking water samples it has produced results of known quality with no modifications necessary for groundwater samples collected at other Region III sites. OASQA would need to review the laboratories complete SOP for the analysis, in order to confidently assess whether or not laboratories modifications to the Method 537 would impact the accuracy of results.

If a modified EPA Method 537 is being used then modifications need to be described and additional data/information are needed such as the Standard Operating Procedure (SOP) from the lab (preferably in advance) and data to demonstrate the performance of the lab's method modifications on these matrices (demonstration of capability/method detection limit, performance testing, and quality control data). Alternatively, a draft direct inject method has produced performance data and Region 5 has developed a method which could be shared for a lab to follow. However, no modifications to the direct inject method would be acceptable.

ACPS and NCC Response to OASQA Comment 11:
Golder provided this comment and request to Eurofins of Lancaster, Pennsylvania and discussed the comment and request with them. Eurofins indicated that their modifications to the method are simply changes to increase the accuracy and precision of the method. For proprietary reasons, Eurofins has provided a redacted version of their SOP for PFAS analysis via Method 537, Revision 1.1 Modified (see attached) for the USEPA's review. This SOP will be included as Attachment F of the revised SAP. If after OASQA's review of the attached SOP, questions or concerns remain regarding Eurofins' modifications to the method, then Eurofins and Golder will schedule and participate in a conference call with OASQA to discuss and address questions and concerns regarding the modifications.

As for use of the direct-injection method in development and use by the USEPA Region 5, please refer to the Response to the USEPA/DNREC Comment 10 above.

OASQA Comment 12. OASQA highly recommends the collection of more than one field blank for PFAS due to their ubiquitous nature. One high-level field blank would reject all data from samples collected that day. Instead if many field blanks are collected at one each per sampling location then only the associated sample with the high-level blank would result in data being rejected.

ACPS and NCC Response to OASQA Comment 12:
As indicated in Responses to the USEPA/DNREC Comments 32 and 33, we have not observed issues associated with PFAS cross-contamination and/or the ubiquitous use of PFAS in our field, rinsate or equipment blanks that we have collected and analyzed at other PFAS sites. Revisions to SAP Section 4.3.3 and/or SOP-2 are not proposed.

OASQA Comment 13. Section 4.4.1 PFAS Decontamination. The use of Ziploc® storage bag to store equipment where the equipment comes in direct contact with the bag has the possibility to transfer PFAS to sampling equipment. It would be impossible to know if this is an issue without first analyzing the Ziploc® bags. If Ziploc® bags are used to store sample bottles during shipping this has no risk due to lack of direct contact.

ACPS and NCC Response to OASQA Comment 13:
See Response to the USEPA/DNREC Comment 32 above.

OASQA Comment 14. Environmental Consultant (EC) and the Laboratory of choice should be documented before next submission of completed QAPP/SAP. In addition, QAPP/SAP should include the QAP and SOP for the laboratory.

ACPS and NCC Response to OASQA Comment 14:
The ACPS and NCC anticipate that there will be two ECs involved in the project through implementation of the Work Plan. The laboratory(ies) of choice is (are) currently in discussion and will be documented with the revised SAP which will include the QAP and SOP for the laboratory(ies).

GWA Recommendations with ACPS and NCC Responses

GWA Comment/Recommendation 1. Well P4 Cap and Plug. Golder reported during their sampling of this well that the flush mount well cap appeared to be in a topographically low position with a loose plug in the well. Maintenance of this well cap is critical for this well and an upgrade or improved flush mount cap is recommended.

ACPS and NCC Response to GWA Comment/Recommendation 1:
Options will be reviewed during the upcoming field activities for resetting the surface completion on this well. In addition, the expansion plug will be inspected during the semi-annual monitoring events to ensure it is maintained in an expanded and secure (not loose) position within the top of the PVC well casing. If the expansion plug is not able to be expanded enough to prevent infiltration of overland flow during precipitation events into the PVC well casing, then the expansion plug will be replaced.

GWA Comment/Recommendation 2. The recent installation of replacement well 6R at Llangollen did not show the presence of the clay layer that splits the upper and lower UPA. If a geophysical log of 22L is not available, a through the casing gamma log of 22L should be added to the Work Plan.

ACPS and NCC Response to GWA* Comment/Recommendation *2:
Monitoring well MW-22L is not a known/existing monitoring point identification for this Site; therefore, the Parties responding to these comments assume that this comment is in reference to existing monitoring well MW-22N. As such, the boring and monitoring well installation log for MW-22N was reviewed (see logs attached as Attachment 6 to this response to comments; to the best of our knowledge a geophysical log is not available). Based on the log, there are silty clays with fine sand and iron ore lenses from 82 to 153 ft-bgs separating fine-to coarse-sand and gravel (72 to 82 ft-bgs) interpreted to be the UPA upper sand from fine-to coarse-sand and gravel (153 to 159 ft-bgs) interpreted to be the UPA lower sand at this location. White clay interpreted to be the Middle Potomac Clay is encountered at 159 ft-bgs (the screen interval for well MW-22N is 139 to 159 ft-bgs). Based on this interpretation, there appears to be separation between the UPA upper and lower sand in the area of well MW-22N. Proposed monitoring well MW-22NU will be installed near existing monitoring well MW-22N using rotosonic drilling techniques which provide a continuous core; therefore, presence (or absence) of a dividing clay (UPDC) can be confirmed

while advancing this boring. As such, the ACPS and NCC have not added geophysical logging of existing well MW-22N to the revised Work Plan or SAP.

GWA Comment/Recommendation 3. The use of Wells 38N and 49N as monitoring points is not recommended as a long-term option. ... As with 22[N], if geophysical logs of 38N and 49N are not available, through the well gamma logging is recommended. Eventual replacement of 38N and 49N with shallow and deep monitoring well pairs should be considered. Data on vertical gradients and the extent of the clay layer obtained from the new well installation will provide insight on vertical movement and the need for well replacement.

ACPS and NCC Response to GWA* Comment/Recommendation *3:

The boring and monitoring well installation logs for MW-38N and MW-49N were reviewed (see logs included as Attachment 6 to this response to comments; to the best of our knowledge geophysical logs are not available for wells MW-38N and MW-49N). Based on the boring log for well MW-38N, there does not appear to be a dividing clay reflected in the log between the UPA upper and lower sands at that well location. Based on the boring log for MW-49N, there does not appear to be a distinct dividing clay (UPDC) reflected in the log. The log for well MW-49N includes "lenses of clay" within the UPA upper sand (as interpreted between the UPCU and the coarser sands above the MPC), whereas the log for well MW-38N does not reference clay within the UPA upper/lower sand interval between the interpreted UPCU and the interpreted MPC.

As indicated in the Response to the USEPA/DNREC Comment 16 (see Response to USEPA/DNREC Comment 16 for additional details), based on the recommendations of the USEPA/DNREC and GWA regarding replacement of long-screen wells with short-screen well clusters, the ACPS and NCC recommend that after performance and evaluation of the data from "Phase 1" that a well pair will be installed between existing wells P-4 and MW-38N. As for replacement of long-screen well MW-49N, the Parties do not recommend replacement of this well at this time for the following reasons:

1) *Based on existing data, it is uncertain if this well is located downgradient of the Western Lobe. Additional data collected from "Phase 1" of the investigation will aid in the interpretation of the groundwater flow direction downgradient of the Western Lobe.*

2) *With the apparent lack of a distinct dividing clay (UPDC) in well MW-49N and its closer proximity to higher producing wells within AWC's Llangollen wellfield than other monitoring wells "downgradient" of the Western Lobe, a long screen well (such as existing well MW-49N) across both the UPA upper and lower sands is more representative of the water quality that will be observed in AWC's long-screen production wells (noting that a flow-weighted average sample would need to be collected to evaluate the concentrations) than a short-screened well pair.*

GWA Comment/Recommendation 4. Recovery Well 10 Screen Interval. Recovery Well 10 is also included in the Work Plan as an upper UPA sampling point. … GWA could not locate a screen depth. The screen depth of this well should be verified.

ACPS and NCC Response to GWA* Comment/Recommendation *4:

The screen interval for well RW-10 is from 77 to 102 ft-bgs based on the June 3, 1980 log by A.C. Schultes & Sons, Inc. The borings logs are attached and will be included as Attachment 6 of the revised Work Plan.

GWA Comment/Recommendation 5. Recovery Well 10 Sampling Results. The historical sampling results from RW-10 show elevated iron and manganese concentrations with historic detection of dissolved oxygen. The last samples in March and April of 2016 included in the Ruth Associates, Inc. report show iron and manganese sample results of 17 to 27 mg/l of iron and nearly 1 mg/l manganese with no detection of dissolved oxygen. Samples from 2010 and 2011 were opposite results with qualified or non-detect results for iron and manganese and dissolved oxygen at roughly 3 to 4 mg/l. Results prior to that have mixed results. The condition of this well should be reviewed prior to inclusion in the sampling plan.

ACPS and NCC Response to GWA* Comment/Recommendation *5:
Minor modifications were made to the purging and sampling methodology in 2016. The changes in concentrations observed may be due to these changes.

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ATTACHMENTS

Attachments referenced herein and associated with the Revised Work Plan (Note: new tables, figures and attachments are being added as indicated below; therefore, subsequent tables, figures and attachments will be renumbered in the revised work plan):

- Revised Table 1 - Sampling Locations, Frequency and Parameters
- Table 2 (new) - Monitoring Point Construction Information
- Table 3 (new) - Monitoring Point Elevation Discrepancies
- Revised Figure 2 - Existing and Proposed Monitoring Well Network for ACL Western Lobe Investigation
- Figure 4 (new) - Water Elevations in the Army Creek Landfill Gas Vent Water and Vicinity
- Figure 5 (new) - Western Lobe Area - Groundwater Elevations 2004-2007
- Revised Figure 4 (now Figure 6) - Locations of Proposed Wells to be Included in ACL's PFAS Monitoring Program
- Attachment 2, Figure 2-1 (new) - Monitoring Well Locations
- Attachment 3 (new) - Summary of Water-Level Elevations for Pump-and-Treat Suspension Pilot Test, Vicinity of the Army Creek and Delaware Sand & Gravel Landfills
- Attachment 6 (new) - Available Boring and Monitoring Well Logs

Attachments referenced herein and associated with the Revised SAP (Note: new tables and attachments are being added as indicated below; therefore, subsequent tables and attachments will be renumbered in the revised SAP):

Table 1 (new) - Data Quality Objectives
Table 2 (new) - Decision Thresholds / Action Levels
Attachment F (new) - Eurofins PFAS Standard Operating Procedure (Redacted)

Attachments referenced herein that will not be included in Revised Work Plan or SAP:

Technical Memorandum - Review of Tentatively Identified Compounds in Groundwater, Delaware Sand & Gravel Superfund Site, New Castle, Delaware by Golder Associates Inc. dated December 21, 2016

ATTACHMENTS ASSOCIATED WITH REVISED WORK PLAN

(Note: new tables, figures and attachments are being added as indicated below; therefore, subsequent tables, figures and attachments will be renumbered in the revised Work Plan)

TABLES

TABLE 1
PROPOSED MONITORING PROGRAM
ARMY CREEK LANDFILL, NEW CASTLE, DELAWARE

Monitoring Location	Well Type	PFAS	Western Lobe	Supply Wells	Water Levels
MW-28	Former Recovery	X			X
MW-29	Former Recovery	X			X
MW-31	Former Recovery	X			X
RW-10	Former Recovery	X	X		X
BW-1	Existing Monitoring	X			X
BW-2	Existing Monitoring	X			X
BW-3	Existing Monitoring	X			X
MW-40	Existing Monitoring	X			X
MW-38N	Existing Monitoring	X	X		X
P-4	Existing Monitoring	X	X		X
P-4L	Proposed Monitoring	X	X		X
WL-1U	Proposed Monitoring	X	X		X
WL-1L	Proposed Monitoring	X	X		X
P-5U	Existing Monitoring				X
P-5L	Existing Monitoring				X
P-6	Existing Monitoring				X
MW-22N	Existing Monitoring	X	X		X
MW-22NU	Proposed Monitoring	X	X		X
MW-26N	Existing Monitoring				X
MW-49N	Existing Monitoring	X	X		X
MW-54	Existing Background	X			X
MW-56	Existing Background	X			X
MW-58	Existing Background	X			X
MW-18	Existing Monitoring				X
DGC-10S	Existing Monitoring				X
DGC-10D	Existing Monitoring				X
DGC-11S	Existing Monitoring				X
DGC-11D	Existing Monitoring				X
GV-1	Gas Vent	X			X
GV-7	Gas Vent	X			X
GV-9	Gas Vent	X			X
GV-13	Gas Vent	X			X
GV-14	Gas Vent	X			X
GV-17	Gas Vent	X			X
GV-29	Gas Vent	X			X
GV-46	Gas Vent	X			X
GV-48	Gas Vent	X			X
GV-51	Gas Vent	X			X
AWC-2	Supply Well			X	
AWC-G3R	Supply Well			X	
AWC-6R	Supply Well			X	
AWC-7	Supply Well			X	

5/29/18

Notes:

X - Groundwater samples will be analyzed for PFAS suite, consistent with the PFAS suite for DS&G, plus field parameters.
Samples from gas vents will be analyzed for PFAS suite only.

X - Analytical parameters will include total and dissolved iron, total and dissolved manganese, total and dissolved cobalt, and field parameters. The semi-annual events (April and October) will also include VOCs and cations and anions as follows: calcium, magnesium, potassium, sodium, ammonia, nitrate, nitrite, sulfate, sulfide, chloride, and bicarbonate.

X - Supply wells will be sampled by AWC monthly for iron and manganese analyses, and quarterly for cobalt.
Addition of other parameters is under consideration by AWC. Only wells that are operating will be sampled during each event.

X - A complete round of water levels will be measured synoptically at all wells, within 48 hours of the completion of the sampling event.

(1) - PFAS monitoring event will be conducted synoptically during the first DS&G event performed after the new wells are installed.

(2) - Western Lobe Study will be conducted quarterly for four quarters, two of which will be done at same time as annual/semi-annual events.

(3) - Field Indicator Parameters include temperature, specific conductance, pH, oxidation-reduction potential, dissolved oxygen and turbidity.

Table 2
Monitoring Point Construction Information
Army Creek Landfill Superfund Site
New Castle, Delaware

Monitoring Point ID	Constructed Use	Inside Diameter (in)	Construction Material	Screened Interval (ft-bgs)	Screen Length (ft)	Screened Unit	Surface Completion	Sounded Depth (ft-btoc)	Proposed Sampling Depth (ft-btoc)
MW-28	Former Extraction Well	6	Steel	40 - 120	80	UPA upper and lower sand	Standpipe	111.6	50 and 90
MW-29	Former Extraction Well	6	Steel	34 - 113	79	UPA upper and lower sand	Standpipe	110.5	39 and 85
MW-31	Former Extraction Well	6	Steel	59 - 105	46	UPA upper and lower sand	Standpipe	112.1	75 and 95
RW-10	Former Extraction Well	10	Steel	77 - 102	25	UPA upper sand	Standpipe	104	90
BW-1	Monitoring Well	4	PVC	106.5 - 126.5	20	UPA upper sand	Standpipe	130.6	126
BW-2	Monitoring Well	4	PVC	105 - 125	20	UPA upper sand	Standpipe	143.1	133
BW-3	Monitoring Well	4	PVC	50 - 135	85	UPA upper sand	Standpipe	125	55 and 92
MW-40	Monitoring Well	4	PVC	110 - 140	30	UPA lower sand	Standpipe	142.1	125
MW-38N	Monitoring Well	4	PVC	72 - 132	60	UPA upper and lower sand	Flush mount	131.2	90 and 120
P-4	Monitoring Well	2	PVC	115 - 125	10	UPA upper sand	Flush mount	124.9	120
P-4L	Monitoring Well (proposed)	2 (proposed)	PVC (proposed)	TBD	10 (proposed)	UPA lower sand (proposed)	Flush mount (proposed)	TBD	TBD
WL-1U	Monitoring Well (proposed)	2 (proposed)	PVC (proposed)	TBD	10 (proposed)	UPA upper sand (proposed)	Standpipe (proposed)	TBD	TBD
WL-1L	Monitoring Well (proposed)	2 (proposed)	PVC (proposed)	TBD	10 (proposed)	UPA lower sand (proposed)	Standpipe (proposed)	TBD	TBD
P-5U	Monitoring Well	4	PVC	70 - 80	10	UPA upper sand	Standpipe	82.8	NA
P-5L	Monitoring Well	4	PVC	126 - 136	10	UPA lower sand	Standpipe	138	NA
P-6	Monitoring Well	2	PVC	100 - 110	10	UPA upper sand	Flush mount	110.5	NA
MW-22N	Monitoring Well	4	PVC	139 - 159	20	UPA lower sand	Flush mount	159.18	149
MW-22NU	Monitoring Well (proposed)	2 (proposed)	PVC (proposed)	TBD	10 (proposed)	UPA upper sand (proposed)	Flush mount (proposed)	TBD	TBD
MW-26N	Monitoring Well	4	PVC	108 - 168	60	UPA lower sand	Standpipe	167.41	NA
MW-49N	Monitoring Well	4	PVC	72 - 132	60	UPA upper sand	Flush mount	156.97	135
MW-54	Monitoring Well	4 (assumed)	PVC (assumed)	40 - 50	10	UPA upper sand	Standpipe	unknown	TBD - no log
MW-56	Monitoring Well	4	PVC	75 - 100	25	UPA upper sand	Standpipe	unknown	85
MW-58	Monitoring Well	4	PVC	95 - 110	15	UPA upper sand	Standpipe	unknown	75 and 95
MW-18	Monitoring Well	1	PVC	80 - 90	10	UPA upper sand	Standpipe	90.5	NA
DGC-10S	Monitoring Well	4	PVC	93 - 113	20	UPA upper sand	Standpipe	115.4	NA
DGC-10D	Monitoring Well	4	PVC	128 - 138	10	UPA lower sand	Standpipe	138.4	NA
DGC-11S	Monitoring Well	4	PVC	70 - 80	10	UPA upper sand	Standpipe	79.9	NA
DGC-11D	Monitoring Well	4	PVC	105 - 115	10	UPA upper sand	Standpipe	115	NA
GV-1	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	23.59	NA
GV-7	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	27.3	NA
GV-9	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	19.94	NA
GV-13	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	22.3	NA
GV-14	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	25.77	NA
GV-17	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	23.8	NA
GV-29	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	24.65	NA
GV-46	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	25.77	NA
GV-48	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	31.9	NA
GV-51	Former Gas Vent	4	PVC	unknown	unknown	Landfilled Material	Standpipe	29	NA

Notes:

1.) MW-22N, MW-26N and MW-49N sounded depth measurements collected on September 14, 2012 by Golder Associates; GV sounded depth measurements collected on September 27, 2004 by Rizzo Associates; all other sounded depth measurements collected February 29 through March 2, 2016 by Ruth Associates.
2.) ft-bgs = feet below ground surface
3.) ft-btoc = feet below top of casing
4.) ft-msl = feet mean sea level
5.) in = inches
6.) NA = not applicable
7.) PVC = poly-vinyl-chloride
8.) TBD = to be determined
9.) TOC = top of casing
10.) UPA = Upper Potomac Aquifer

Table 3
Monitoring Point Elevation Discrepancies
Army Creek Landfill Superfund Site
New Castle, Delaware

Monitoring Point ID	Casing Reference Point	Top of Casing (TOC) Elevation used by Golder 1929 NGVD		Top of Casing (TOC) Elevation used by RAI Datum Unknown		Difference in TOC Elevation (feet; Golder-RAI)	Observations / Recommendations
		Elevation (ft-msl)	Source of Information	Elevation (ft-msl)	Source of Information		
MW-28	Steel	using RAI info	NA	20.37	2001 TetraTech Rpt	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-29	Steel	using RAI info	NA	17.38	2001 TetraTech Rpt	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-31	Steel	13.77	2012 TWT Survey	13.45	unknown	0.32	Use TWT Survey Data
RW-10	Steel	using RAI info	NA	8.67	2001 TetraTech	NA	**Datum Unknown, Resurvey using 1929 NGVD**
BW-1	PVC	30.32	2015 TWT Survey[1]	29.71	unknown	0.61	**Resurvey using 1929 NGVD**
BW-2	PVC	33.68	2015 TWT Survey[1]	33.09	unknown	0.59	**Resurvey using 1929 NGVD**
BW-3	PVC	using RAI info	NA	7.00	2001 TetraTech Rpt	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-40	PVC	36.32	2015 TWT Survey	36.05	unknown	0.27	Use TWT Survey Data
P-4	PVC	using RAI info	NA	47.89	2002 TetraTech Rpt	NA	**Datum Unknown, Resurvey using 1929 NGVD**
P-5U	PVC	15.30	2013 TWT Survey	14.71	unknown	0.59	Possible datum difference, use TWT Survey Data
P-5L	PVC	14.91	2013 TWT Survey	14.34	unknown	0.57	Possible datum difference, use TWT Survey Data
P-6	PVC	43.06	2013 TWT Survey	42.39	unknown	0.67	Possible datum difference, use TWT Survey Data
MW-22N	PVC	51.68	2012 TWT Survey	50.71	unknown	0.97	Use TWT Survey Data
MW-26N	PVC	36.76	2012 TWT Survey	35.41	unknown	1.35	Use TWT Survey Data
MW-38N	PVC	35.55	2015 TWT Survey	35.05	unknown	0.50	Use TWT Survey Data
MW-49N	PVC	51.41	2012 TWT Survey	50.96	unknown	0.45	Use TWT Survey Data
MW-54	PVC	using RAI info	NA	24.95	unknown	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-56	PVC	using RAI info	NA	22.03	unknown	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-58	PVC	using RAI info	NA	11.14	unknown	NA	**Datum Unknown, Resurvey using 1929 NGVD**
MW-18	Steel	6.97	2012 TWT Survey	7.40	unknown	-0.43	Use TWT Survey Data
DGC-10S	PVC	41.92	2012 TWT Survey	40.94	unknown	0.98	Use TWT Survey Data
DGC-10D	PVC	41.77	2012 TWT Survey	42.11	unknown	-0.34	Use TWT Survey Data
DGC-11S	PVC	38.54	2012 TWT Survey	37.80	unknown	0.74	Possible datum difference, use TWT Survey Data
DGC-11D	PVC	38.93	2012 TWT Survey	38.16	unknown	0.77	Possible datum difference, use TWT Survey Data

Notes
1. Well casing have been extended since this time and there may be survey discrepancies.
2. Golder estimates that difference in datum from 1929 NGVD to 1988 NAVD would be about 0.65 feet +/- 0.1 feet for this area.
3. TWT = Taylor Wiseman Taylor (licensed surveyor)
4. ft-msl = feet-mean sea level
5. NA = not applicable
6. RAI = Ruth Associates Inc.
7. PVC = polyvinyl chloride

FIGURES

Figure 2.
Existing and Proposed Monitoring Network for ACL Western Lobe Investigation

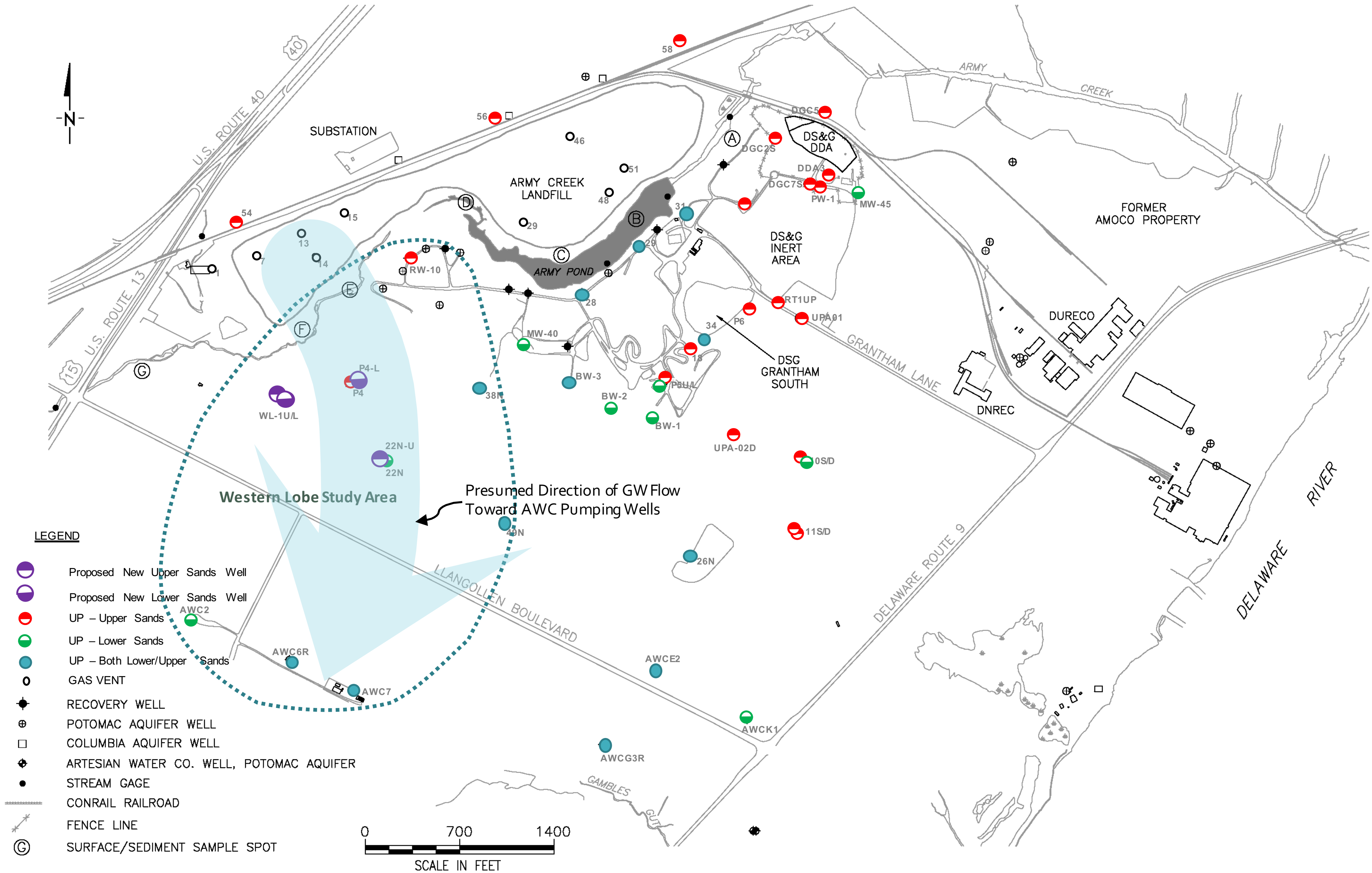


Figure 4: **Groundwater Elevations in the Army Creek Landfill Gas Vents and Vicinity**

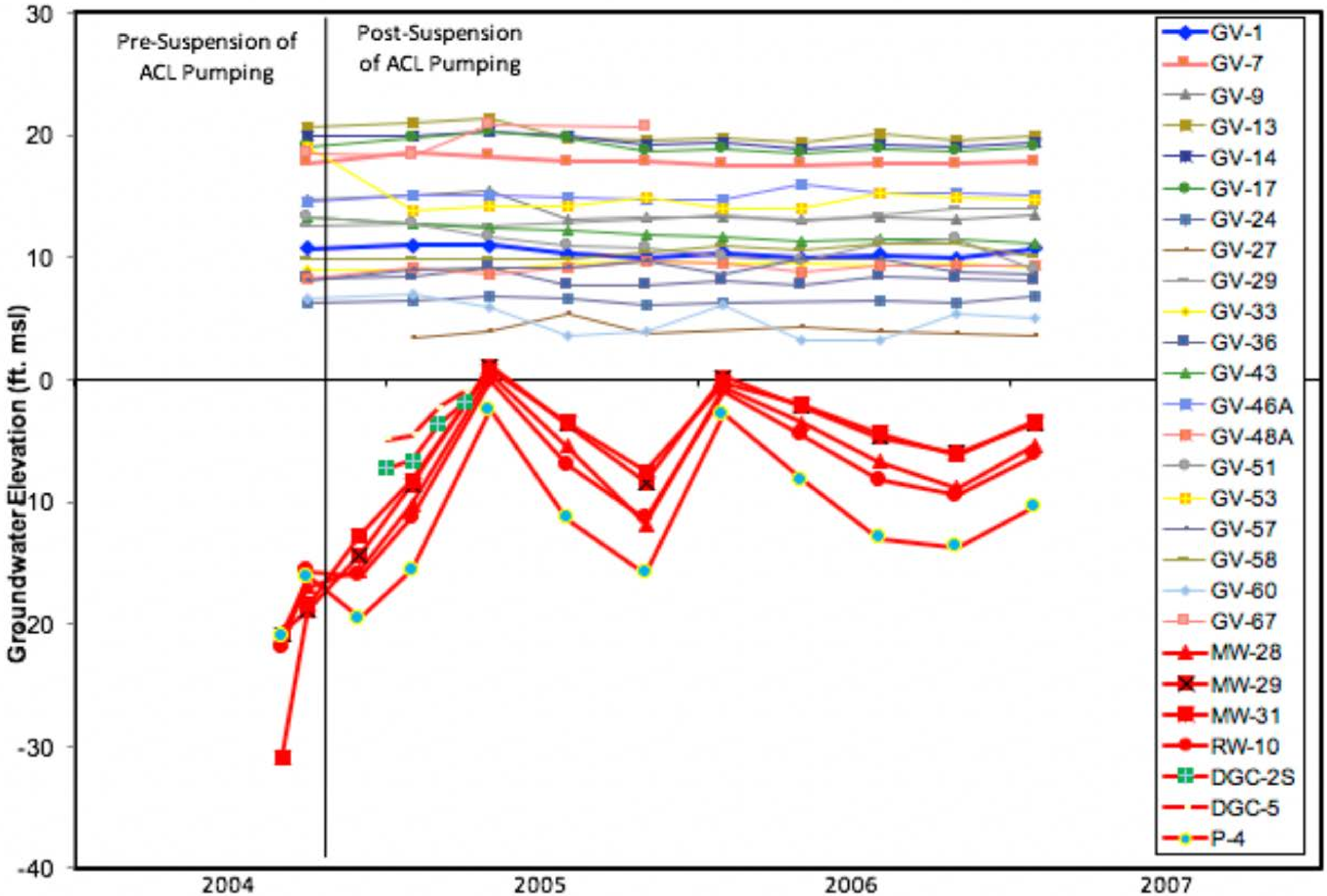


Figure 5: Western Lobe Area - Groundwater Elevations 2004-2007

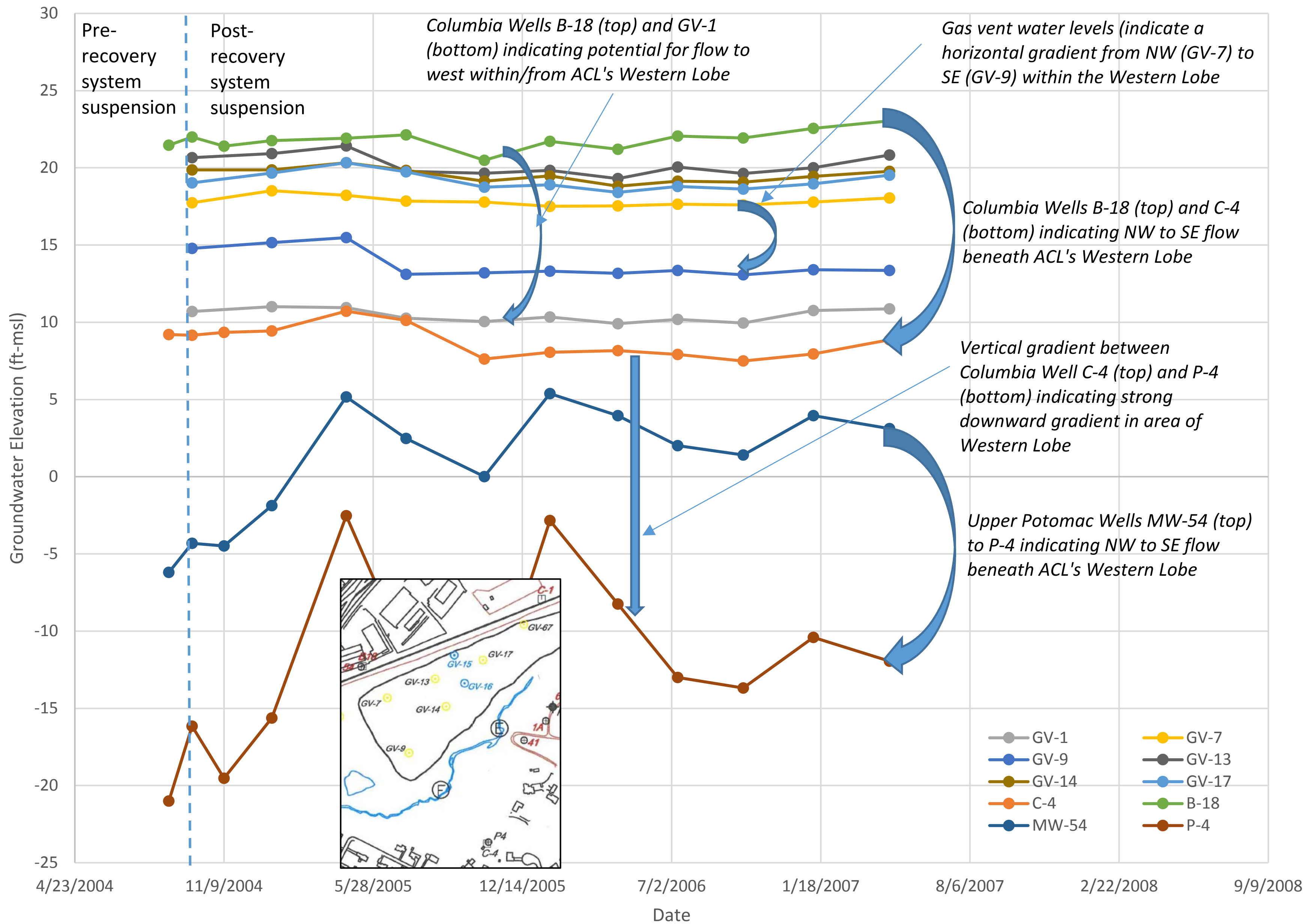
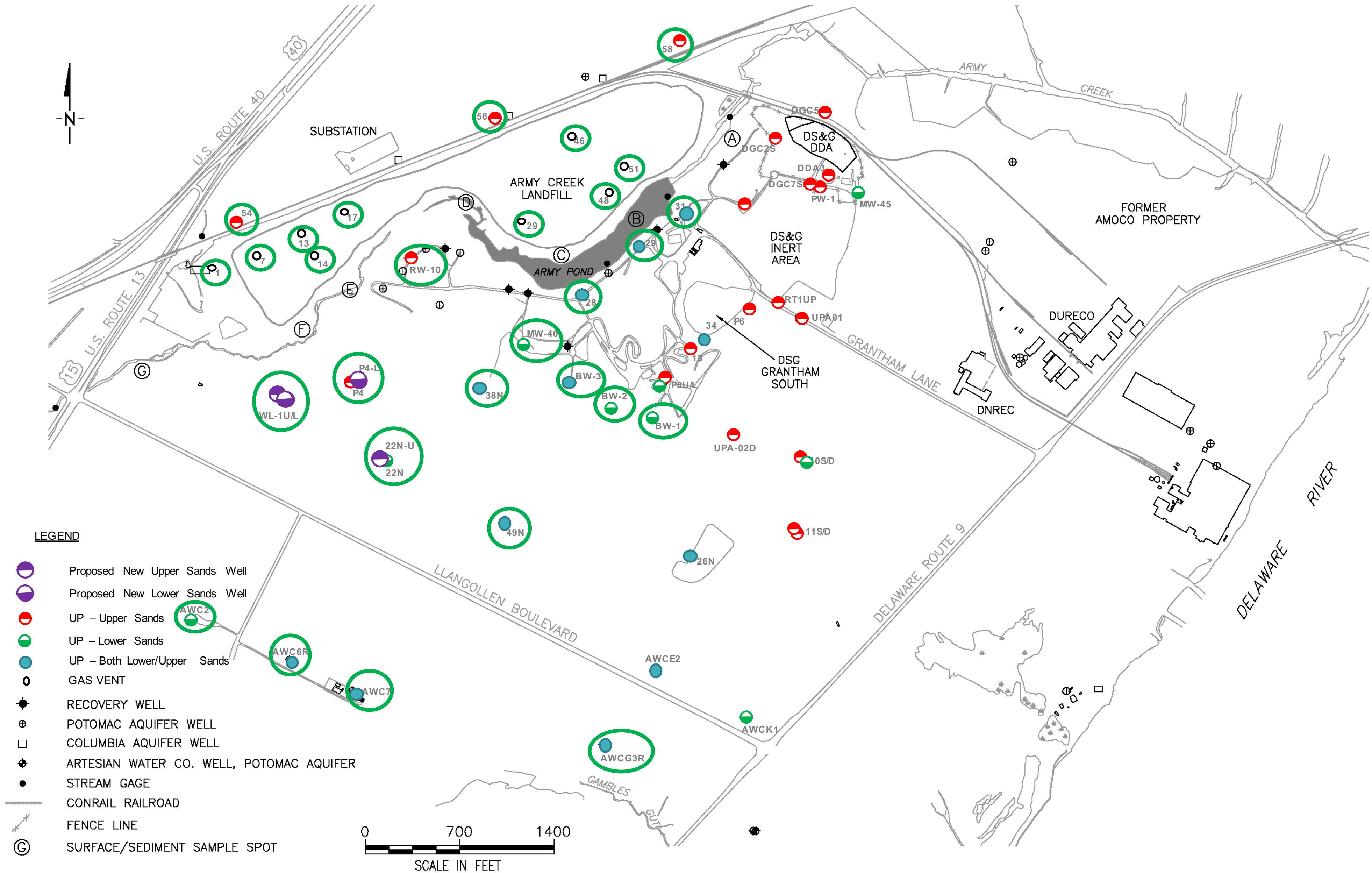


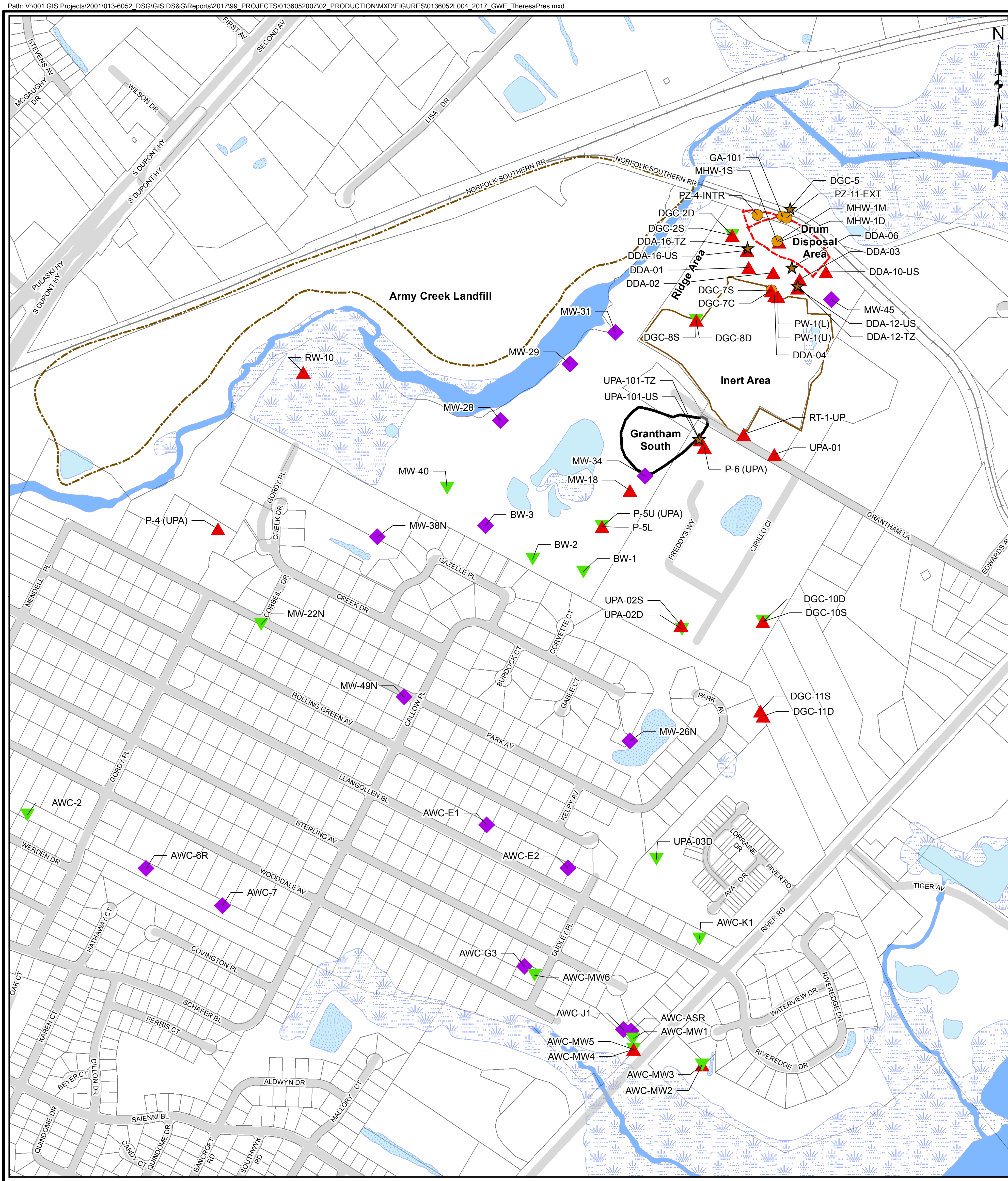
Figure 6.
Locations of Proposed Wells to be included in ACL's PFAS Monitoring Program



ATTACHMENT 2, FIGURE 2-1 (NEW)

MONITORING WELL LOCATIONS

Path: V:\001 GIS Projects\2001\013-6052_DSG\GIS DS&G\Reports\2017\99_PROJECTS\0136052007\02_PRODUCTION\MXD\FIGURES\0136052L004_2017_GWE_TheresaPres.mxd



LEGEND

- ★ Well screened in UPCU Transition Zone
- ▲ Well screened in UPA Upper Sand
- ▼ Well screened in UPA Lower Sand
- ◆ Well screened across UPA Upper Sand and Lower Sand
- ● Well screened in Columbia Aquifer

REFERENCE

Base data taken from New Castle County Delaware, Department of Land Use, "eParcel View Map" web site GIS data download. Data acquired 07/29/2013.

0 300 600 1,200 Feet

1 inch = 600 feet

ATTACHMENT FIGURE 2-1

REVIEW	TAM	1/5/2018
CHECK	RWB	1/5/2018
GIS	SHL	1/5/2018
DESIGN	RWB	1/5/2018
REV. 0	SCALE: AS SHOWN	
FILE No.	0136052L004_2017_GWE_TheresaPres	
PROJECT No.	013-6052.007	

TITLE

MONITORING WELL LOCATIONS

PROJECT

Army Creek Landfill Superfund Site New Castle, Delaware

ATTACHMENT 3 (NEW)

SUMMARY OF WATER-LEVEL ELEVATIONS FOR PUMP-AND-TREAT SUSPENSION PILOT TEST, VICINITY OF THE ARMY CREEK AND DELAWARE SAND & GRAVEL LANDFILLS

Attachment 3

Summary of Water-Level Elevations for Pump-and-Treat Suspension Pilot Test
Vicinity of the Army Creek and Delaware Sand & Gravel Landfills

	Pre-Suspension		Post-Suspension										
	08/27/04	09/27/04	11/09/04	01/12/05	04/22/05	07/11/05	10/24/05	01/20/06	04/21/06	07/10/06	10/06/06	01/08/07	04/20/07
Monitoring/Recovery Wells													
MW-1A	-21.83	-15.42	-15.89	-11.18	0.05	-6.82	-11.41	-0.71	-4.39	-8.10	-9.39	-6.05	-7.98
DGC-10S	-23.88	-16.18	-23.10	-17.43	-3.40	--	-20.43	-4.00	-10.22	-16.36	-14.78	-13.00	-15.13
DGC-10D	-22.43	-15.54	-25.73	-16.38	-2.24	--	-19.96	-3.19	-9.13	-15.39	-13.79	-11.99	-14.08
DGC-11S	-18.28	-13.80	-20.35	-17.03	-2.83	--	-18.54	-3.71	-8.42	-14.45	-14.54	-11.04	-13.31
DGC-11D	-24.64	-15.78	-24.86	-19.02	-3.74	--	-23.50	-4.74	-11.59	-18.46	-16.44	-14.64	-16.89
MW-18	--	-15.52	-18.82	--	-0.88	-10.43	-15.48	-1.48	-6.22	-11.06	-10.96	-8.47	-10.32
MW-22N	-22.27	-16.54	-22.20	-17.93	-3.71	-14.10	-21.39	-3.93	-10.68	-15.95	-15.60	-11.09	-14.97
MW-26N	-27.35	-16.85	-27.19	-20.74	-4.03	-19.74	-24.97	-4.79	-13.27	-20.72	-17.65	-16.17	-19.06
MW-27	-21.32	-16.09	-16.62	-11.64	-0.22	-7.27	-12.15	-1.00	-4.86	-8.59	-9.87	-6.61	-7.05
MW-28	-20.70	-16.97	-15.65	-10.25	0.46	-5.43	-11.82	-0.58	-3.59	-6.74	-8.88	-5.36	-5.23
MW-29	-20.86	-18.88	-14.35	-8.62	1.11	-3.64	-8.45	0.24	-2.22	-4.78	-5.98	-3.58	-3.52
MW-31	-30.95	-18.42	-12.71	-8.26	0.75	-3.50	-7.54	-0.21	-2.07	-4.40	-6.15	-3.40	-3.27
MW-34	-22.26	-16.17	-19.96	-14.36	-1.67	-11.47	-16.41	-2.70	-7.52	-12.42	-12.21	-9.80	-11.26
MW-38N	-21.89	-16.41	-19.24	-14.25	-0.44	-10.32	-15.28	-2.08	-7.20	-11.87	-12.36	-9.29	-10.53
MW-40	-21.54	-16.76	-17.90	-12.84	-0.73	-8.76	-13.90	-1.50	-5.97	-10.23	-11.23	-7.97	-8.86
MW-41	-21.56	-15.59	-16.35	-11.60	-0.19	-7.31	-11.82	-0.92	-4.80	-8.60	-9.82	-6.55	-7.46
MW-45	-15.95	-13.21	-13.59	-9.43	-0.49	-5.80	-9.31	-1.32	-3.75	-6.66	-7.43	-5.11	-5.10
MW-49N	-24.75	-16.57	-24.64	-18.99	-3.46	-16.64	-18.41	-3.69	-11.65	-17.96	-16.12	-14.45	-16.69
MW-54	-6.20	-4.31	-4.48	-1.88	5.16	2.47	0.01	5.38	3.95	2.01	1.41	3.96	3.11
MW-56	-14.00	-11.48	-9.41	-4.84	3.36	0.04	-3.56	2.49	1.00	-0.61	-2.29	0.56	0.24
MW-57	-11.08	-9.28	-6.70	-2.93	3.70	1.74	-1.22	3.16	2.22	0.97	-0.39	1.87	1.81
MW-58	-9.33	-8.02	-5.73	-2.56	2.92	1.40	-0.92	2.44	1.63	0.84	-0.59	1.49	1.64
MW-66	-21.59	-15.57	-15.84	--	--	-6.64	-11.24	-0.67	-4.33	-7.91	-9.21	-5.91	-6.78
MW-67	-21.57	-16.07	-16.02	-12.60	-0.72	-8.34	-13.06	-1.46	-5.74	-9.73	-10.85	-7.54	-8.55
MW-68	-22.03	-15.42	-17.02	-10.87	0.18	-6.52	-11.02	-0.63	-4.24	-7.70	-9.07	-5.79	-6.60
MW-69	-21.40	-18.28	-15.65	-9.98	0.17	-5.28	-10.11	-0.79	-3.53	-6.41	-8.19	-5.05	-5.26
P-4	-21.01	-16.16	-19.53	-15.63	-2.53	-11.38	-15.90	-2.84	-8.25	-13.00	-13.69	-10.41	-11.95
P-5L	-23.23	-16.21	-19.48	-16.58	-1.98	-13.20	-18.23	-3.04	-8.61	-14.03	-13.45	-11.06	-12.76
P-5U	-22.08	-16.39	-18.84	-13.75	-1.31	-10.36	-15.53	-2.33	-6.88	-11.38	-11.86	-9.12	-10.13
P-6	-20.44	-17.02	-15.95	-10.73	-0.53	-6.59	-11.02	-1.39	-4.37	-7.54	-8.74	-6.01	-6.25
PW-1 (Dureco)	-56.04	-56.08	-56.44	-55.72	-53.63	--	-56.08	--	--	--	--	--	--
PW-3 (Dureco)	-10.04	-7.25	-10.54	-6.24	-1.49	--	--	--	--	--	--	--	--
RT-1UP	-17.63	-15.30	-18.60	-13.45	-1.66	-11.17	-15.28	--	-6.91	-11.52	-11.53	-9.17	--
RW-1	-26.45	-16.97	-18.12	-12.91	-1.11	-8.72	-14.13	--	--	--	--	--	--
RW10	-21.96	-15.66	-16.05	-11.30	-0.17	-6.95	-11.36	-0.96	-4.59	-8.21	-9.49	-6.20	-7.06
RW-11R	-20.72	-14.35	-15.08	-10.20	0.90	-5.79	-10.38	-0.14	-3.60	-7.20	-8.35	-5.15	-6.28
RW-12	-22.21	-19.49	-13.98	-7.80	0.32	-4.21	-8.32	-0.53	-2.65	-5.05	-6.64	-3.86	-3.90
RW-13	-18.41	-15.93	-12.48	-7.63	0.69	-2.99	-6.56	2.35	2.33	2.56	2.36	3.04	3.69
TW-4	-11.95	-9.67	-11.55	-8.40	-1.15	--	--	--	--	--	--	--	--
B-18	21.46	21.99	21.41	21.76	21.91	22.14	20.49	21.72	21.21	22.06	21.94	22.56	23.04
BW-1	-23.98	-16.14	-22.22	--	-2.26	-14.17	-19.33	-3.21	-9.38	-15.07	-14.21	-11.94	-11.87
BW-2	-23.71	-16.66	-21.56	-16.00	-2.18	-13.27	-18.06	-3.07	-8.83	-14.11	-13.78	-11.28	-12.89
BW-3	-22.14	-16.95	-18.90	-13.58	-1.06	-9.88	-14.96	-1.95	-6.55	-10.97	-11.88	-8.92	-9.85
C-1	18.99	18.50	18.97	19.31	19.98	19.16	--	18.26	17.59	18.75	17.45	18.08	19.67
C-2	<1.74	<1.74	<1.74	<1.74	7.98	4.96	12.80	4.66	5.01	5.81	4.31	4.75	6.48
C-3	< -6.02	< -6.02	< -6.02	< -6.02	--	2.46	< -6.02	2.44	2.57	2.83	0.69	2.31	3.97
C-4	9.21	9.16	9.34	9.44	10.72	10.12	7.62	8.06	8.17	7.91	7.49	7.95	8.87
C-5	-15.35	-13.37	-11.80	-7.83	2.33	-1.14	-7.23	0.64	-0.79	-3.06	-6.62	-2.87	-1.66
C-6	<3.76	<3.76	<3.76	<3.76	4.87	4.06	5.39	3.77	3.73	3.73	<3.37	<3.37	<3.37
DGC-2S	-15.09	-13.34	-10.64	-6.04	1.23	-1.80	-5.24	0.49	-0.82	-2.31	-4.14	-1.64	-1.01
DGC-5	-11.05	-10.10	-8.25	-4.76	0.49	-1.48	-4.20	-0.05	-0.85	-1.44	-3.58	-1.12	-0.60
DGC-7S	-16.32	-14.12	-12.91	-8.37	0.05	-4.32	-7.94	-0.74	-3.20	-5.42	-6.72	-4.48	-3.18
Llangollen Supply Wells													
AWC-2	-34.12	-18.32	-24.05	-34.57	-8.72	-31.22	-32.22	-7.52	-24.37	-29.17	-27.42	-24.72	-27.02
AWC-6	-21.49	-18.59	-26.89	-27.34	-7.69	-24.99	-25.19	-7.19	-17.94	-24.39	-23.09	-23.09	-24.64
AWC-7	-21.47	-18.57	-28.22	-37.62	-7.82	-35.12	-26.92	-6.92	-25.92	-25.67	-24.42	-34.42	-35.47
AWC-G3	-47.32	-11.32	-50.87	-44.67	-5.46	-42.27	-50.66	-6.36	-39.02	-49.07	-44.47	-45.08	-46.82
AWC-K1	-49.29	-16.84	-47.29	-42.49	-4.17	-43.47	-60.14	-5.39	-44.36	-56.39	-50.49	-48.32	-55.94
AWC-MW2R	-33.58	-33.58	-35.84	--	-6.09	-30.24	-34.48	-7.07	-14.52	-34.37	--	-21.41	-24.87

Note - All water level measurements in ft. msl
-- Not measured

Attachment 3 (cont'd)

Summary of Water-Level Elevations for Pump-and-Treat Suspension Pilot Test
Vicinity of the Army Creek and Delaware Sand & Gravel Landfills

	Pre-Suspension	Post-Suspension											
	09/27/04	01/17/05	03/25/05	04/01/05	04/22/05	07/11/05	10/24/05	01/20/06	04/21/06	07/10/06	10/06/06	01/08/07	04/20/07
Gas Vents													
GV-1	10.69	11.01	--	--	10.95	10.26	10.04	10.34	9.91	10.18	9.95	10.76	10.87
GV-7	17.74	18.52	--	--	18.22	17.85	17.78	17.51	17.53	17.65	17.59	17.79	18.05
GV-9	14.79	15.15	--	--	15.48	13.10	13.20	13.31	13.17	13.36	13.07	13.40	13.36
GV-13	20.66	20.92	--	--	21.42	19.77	19.65	19.83	19.30	20.05	19.64	20.00	20.83
GV-14	19.87	19.87	--	--	20.33	19.84	19.14	19.47	18.81	19.13	19.07	19.44	19.77
GV-17	19.03	19.66	--	--	20.33	19.74	18.75	18.91	18.41	18.80	18.63	18.97	19.52
GV-24	6.30	6.42	--	--	6.84	6.56	6.03	6.34	<6.42	6.37	6.21	6.75	6.11
GV-27	<3.34	3.45	--	--	4.02	5.44	3.68	<3.02	4.21	3.92	3.70	3.50	6.91
GV-29	12.49	12.72	--	--	12.57	<12.66	13.16	13.47	12.94	13.37	13.96	13.96	13.57
GV-33	8.9	<8.40	--	--	9.05	9.54	9.65	9.58	9.53	9.26	9.54	9.14	9.15
GV-36	8.23	8.42	--	--	9.20	7.65	7.73	8.14	7.72	8.51	8.27	8.06	8.04
GV-43	13.21	12.66	--	--	12.42	12.22	11.92	11.62	11.27	11.51	11.43	11.20	12.04
GV-46A	14.61	15.03	--	--	15.03	14.82	14.72	14.67	15.95	15.28	15.19	15.09	15.08
GV-48A	8.24	9.11	--	--	8.63	9.18	9.63	9.53	8.82	9.30	9.37	9.29	9.32
GV-51	13.20	2.67	--	--	11.61	10.90	10.68	10.00	9.66	11.09	11.42	8.88	11.99
GV-53	19.11	13.86	--	--	14.09	14.14	14.86	13.93	14.08	15.17	14.89	14.66	14.87
GV-57	8.00	9.05	--	--	9.18	9.23	9.70	8.55	9.79	9.83	8.84	8.69	6.97
GV-58	9.95	9.88	--	--	9.92	<9.91	10.35	10.94	10.53	11.10	11.16	10.04	10.99
GV-60	6.67	7.06	--	--	5.94	3.61	3.88	6.08	3.29	3.27	5.43	5.01	5.91
GV-67	18.41	18.33	--	--	20.77	<19.63	20.63	<18.47	< 18.25	< 18.67	< 18.67	< 18.67	20.10
Surface Water													
SG-1	2.07	Gauge destroyed	--	--	--	--	--	--	--	--	--	--	--
SG-1B	not installed	not installed	1.16	1.16	1.14	0.75	0.90	1.22	0.88	0.99	1.56	--	1.25
SG-2	11.52	dry[a]	--	--	--	--	--	--	--	--	--	--	--
SG-2B	not installed	not installed	11.01	10.98	dry	dry	< 11.84	< 11.84	<11.35	<11.41	11.34	12.04	<11.11
SG-3	10.60	10.77[a]	--	10.71	dry	10.46	< 10.91	<10.78	<10.68	10.70	--	12.24	--
SG-4	not installed	not installed	1.70	1.47	1.46	1.76	1.46	--	1.66	1.50	1.93	2.50	1.66
SG-5	not installed	not installed	1.71	1.46	1.49	1.75	1.46	--	1.44	1.19	1.64	2.26	1.29

[a] - Measured on January 19, 2005
Note - All water level measurements in ft. msl
-- Not measured

ATTACHMENT 6 (NEW)

AVAILABLE BORING AND MONITORING WELL LOGS

WELL FILLED TO 154.'
VERY FINE TO COARSE & GRAVEL

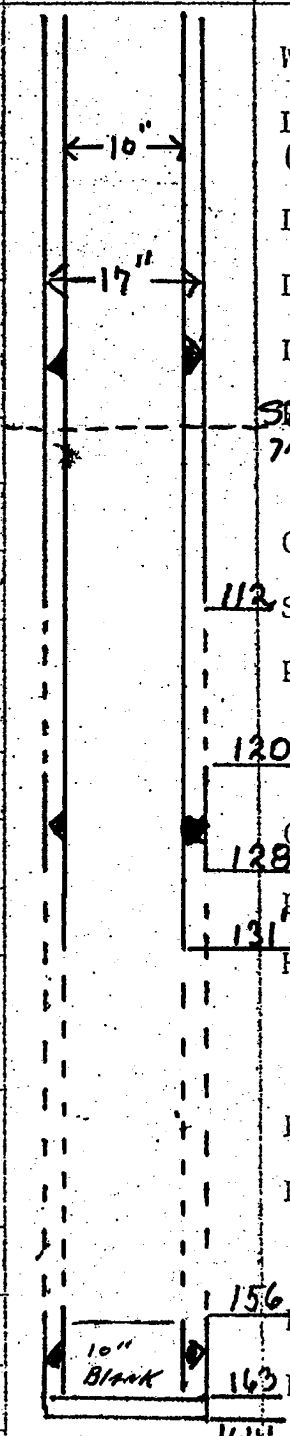
ARTESIAN WATER COMPANY
Newark, Delaware

WELL REPORT

Test Well [ ] Completed Well [X]

Formation Log	Depth in ft. (from G.L.)
TOP SOIL AND CLAY	2-12
SANDY CLAY AND STONES	12-36
SANDY CLAY	36-64
DIRTY SAND AND GRAVEL	64-66
SANDY CLAY	66-70
dirty sand and clay	70-73
CLEAN SAND AND GRAVEL	73-77
SANDY CLAY	77-112
DIRTY FINE SAND	112-120
SANDY CLAY	120-128
DIRTY SAND AND CLAY	128-135
CLEAN FINE SAND	135-142
DIRTY FINE SAND	142-152
sandy clay	
Pump	
14 - 10'-S 140	
2 - 5'-S 10	
Pump 4'-2½ 4-2½	
Suction 1-6 1-6	
155-8½	
Pump Sanded in 18'	

Sketch (with casing & screen details)



Pump Test and Other Information

Well No: 2 Permit No: N/A

Location: LLAGOLLEN
(Draw well location sketch on reverse side.)

Date completed: NOVEMBER 1953

Drilled by: KELLY WELL CO.

Drilling Method: REVERSE ROTARY

Strata SP/Elec Log [ ] Gamma Log [ ]
74'-57

Pump Test Data

Ground Elvn: 11.53' 56' Hrs. Develd:

Static Level: 83.97 8-26-76 74.57-3-18-76 Pmp. Level:

Pmp. Rate (GPM): Hrs. Pmpd:

Water Quality Data

Color: Turbidity:

pH: Iron:

Hardness: Chloride:

Remarks

Excellent [ ] Good [ ] Bad [ ]

Estimated Capacity (GPM):

Reported by:

Date of report:

Well Installation As-Built

Summary Table

Location: LIANGOLLEN

Well Name: 6R

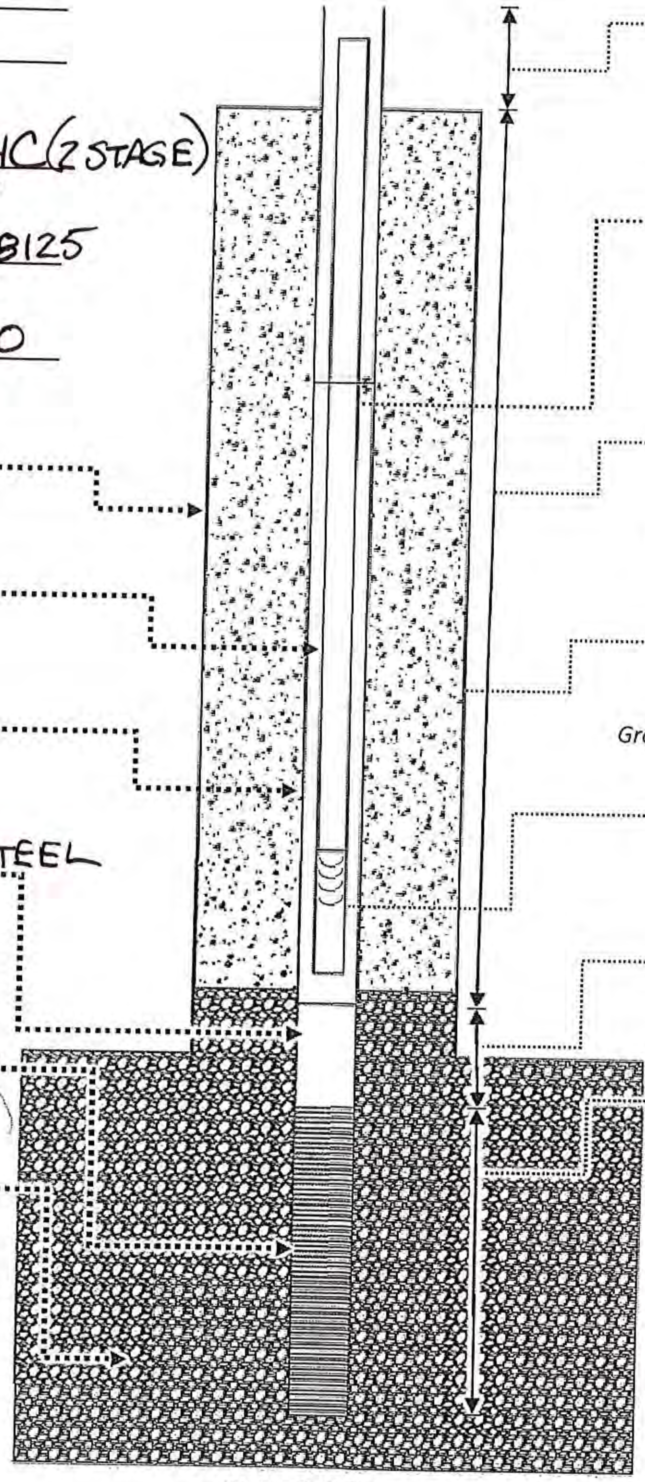
Date: 12/11/17

Pump: GOULDS (*Manufacturer*) 8RJHC(2 STAGE) (*Model*)

Motor: FRANKLIN (*Manufacturer*) 2366178125 (*Model*)

Design Flow: 600 Design TDH: 180

Diam. (in)	Material / Size	
18	STEEL	*Outer Casing*
6	STEEL	*Column Pipe*
12	STEEL	*Inner Casing*
12	STAINLESS STEEL	*Blank*
12	STAINLESS STEEL	*Screen*
24	#2 GRAVEL	*Gravel Pack*



Value	Description
2	Length (ft) *Inner Casing TOC to Ground*
95	Length (ft) *Column Pipe*
100	Length (ft) *Inner Casing Ground to Top of Blank*
100	Length (ft) *Outer Casing Ground to Bottom of Casing*
104	Pump Setting (ft) *TOC to Pump Intake*
5	Length (ft) *Blank*
40	Length (ft) *Screen*

Notes

SCREEN .040

NOT TO SCALE

LAYNE-NEW YORK CO., INC.

1250 WEST ELIZABETH AVE., LINDEN, N. J.

2/3/69

LOG OF WELL

Well No. 7 Job No. M129-68 Test No.

Log of Well for (Owner) Artesian Water Co.

Address 501 Newport Gap Pike, Newport, Wilmington, Del.

Representative, if any

Well Located at Llangolen Estates in Newcastle County, State of Del.

Furnish sketch of location Date Drilling started Date Test Hole Completed

Total depth to bottom of Well 180' Diameter Test Hole Elevation at Ground Level, if available

Elevation at Ground Level, if available Distance from where measurements were taken to ground level 0'

Water stands when not pumping feet inches from the surface of the ground

All Measurements taken from Ground level

THICKNESS OF STRATUM	DEPTH TO BOTTOM OF STRATA	Length of Core Taken	FORMATION FOUND EACH STRATUM	THICKNESS OF STRATUM	DEPTH TO BOTTOM OF STRATA	Length of Core Taken	FORMATION FOUND EACH STRATUM
1	1		Top soil		171		Fine yellow sand light streaks of white clay
4	5		Hard dry clay & sand mixed with gravel & boulders		180		Sand, gray clay
21	26		Fine to coarse sand & gravel & white clay streaks				
4	30		Yellow clay				
14	44		Red clay				
	76		Sandy red clay & light streaks of sand				
18	94		Tough red clay				
3	97		Red sandy clay & hard streaks of sand				
	137		Hard packed fine to medium yellow sand				
4	141		Clay				
	150		Fine to coarse yellow, hard packed sand				

Remarks and opinion of Test

CHECK TYPE OF RIG USED { Reverse Rotary, Cable Tool, Wash, Other?

R. E. Errickson
Driller

996-10-66WP

LLANGOLEN WELLFEILD

WELL#7 FORMATION LOG

0-1' TOP SOIL

1-5' HARD DRY SANDY CLAY MIXED WITH GRAVEL & BOULDERS

5-26' FINE TO COARSE SAND & GRAVEL & STREAKS OF WHITE CLAY

26-30' YELLOW CLAY

30-44' RED CLAY

44-76' SANDY RED CLAY & LIGHT STREAKS OF SAND

76-94' TOUGH RED CLAY

94-97' RED SANDY CLAY & HARD STREAKS OF SAND

97-137' HARD PACKED FINE TO MEDIUM YELLOW SAND

137-141' CLAY

141- 150' FINE TO COARSE YELLOW HARD PACKED SAND

150-171' FINE YELLOW SAND & LIGHT STREAKS OF WHITE CLAY

171-180' SAND & GRAY CLAY

Pump.
JACCU 221. 8BT/624
6x8x1 Head.
S# 2B722061
open Impeller-

Telephone 410-841-6710
Fax # 410-841-6711

A.C. SCHULTES OF MARYLAND, INC.

8221 Cloverleaf Dr., Millersville, MD 21108

Driller's Log

Water Well Contractors

CUSTOMER: Artesian Water Company JOB H6335

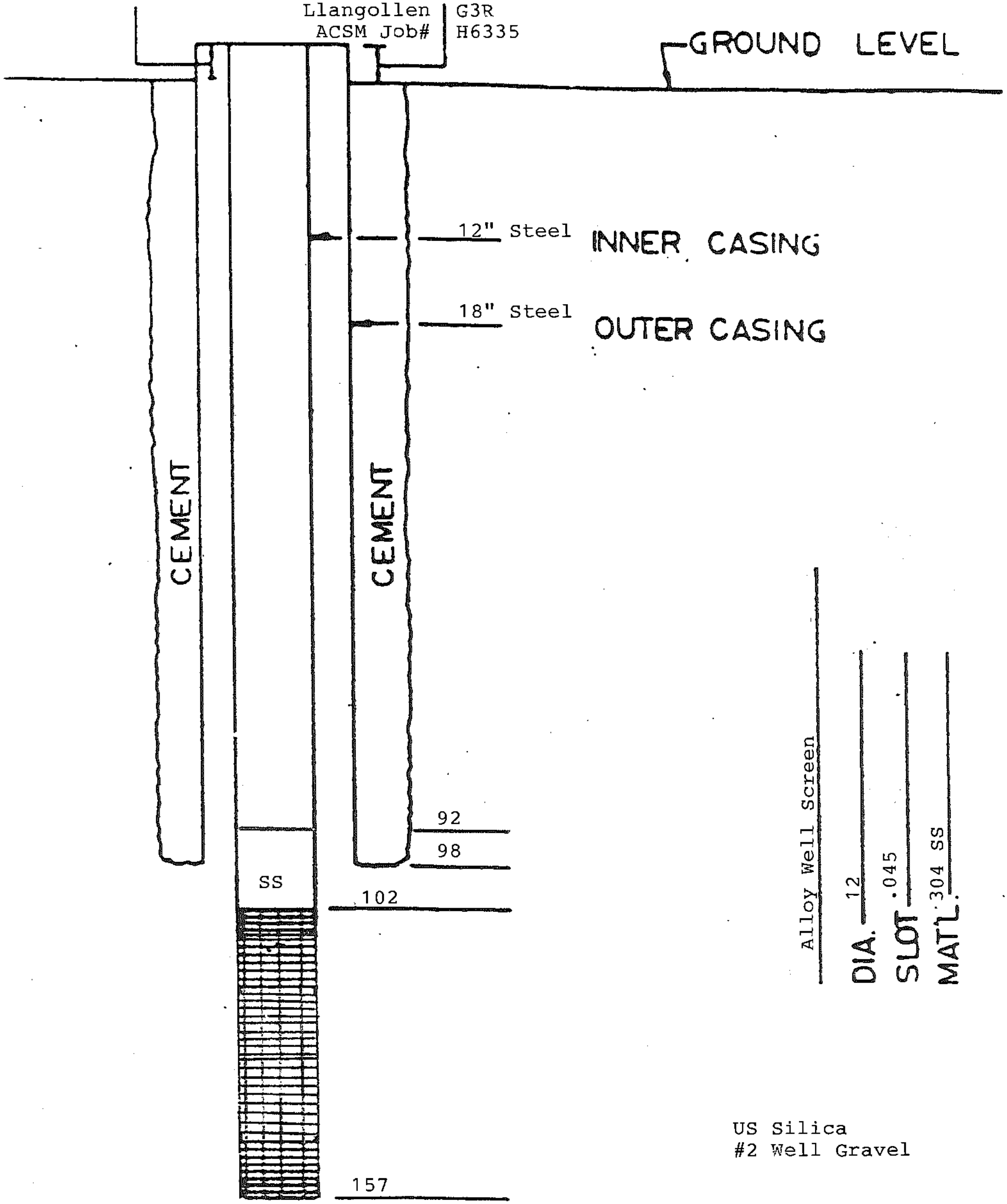
ADDRESS: DUDLEY PL. DATE 10/10/12

LOCATION: NEW CASTLE, DE PERMIT NO. 240617

		FEET FROM GROUND SURFACE 0 TO ____	WELL LOG
GROUND		0-1	Top soil
		1-8	COARSE TO MED SAND W/ SOME PEE GRAVEL
		8-90	MULTI-COLORED CLAY MAINLY RED
		90-91	HARD LAYER
		90-98	MULTICOLORED CLAY W/ SAND
		98-156	COARSE TO MED SAND W/ GRAVEL
		156-162	MED TO FINE SAND W/ SOME MICA
TOTAL DEPTH	CASING		
	SCREEN		
			PILOT HOLE

WELL NO. G-3R	DIAMETER OF WELL	DEPT. OF WELL
HOURS PUMPED	SLOT SIZE	TYPE OF CASING
CAPACITY GPM	DRILLING MACHINE NO. CF-15	LENGTH OF CASING
STATIC LEVEL	DRILLER R. MELSON	DISTANCE TO TOP OF SCREEN
PUMPING LEVEL	GRAVEL	TYPE SCREEN
SPECIFIC CAPACITY	____ BAGS OF	SIZE OF SCREEN
PUMPED WITH	DATE WELL COMPLETED	OUTER CASING SIZE
DEPTH OF GROUT	DRILLER'S HELPER	OUTER CASING DEPTH
DEPTH GRAVEL PACKED		

Proposed Well Design
Artesian Water Company
Llangollen | G3R
ACSM Job# | H6335



PERMIT 240617

TETRA TECH INC.
WELL DRILLING LOG

PERMIT NO.
SHEET: 1 of 1

PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: BW-1	DATE(S) DRILLED: 4/25/94-4/29/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 46'; 10"46' to 126.5'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 126.5'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 126.5'-106.5'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 106.5' - +3' above ground
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 126.5'-101'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 97'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 101'-97'
DEVELOPMENT METHOD: Air Surging/Jetting TIME: 70 minutes	ESTIMATED YIELD: 75 gpm
STATIC WATER DEPTH: DATE: 5/06/94	REFERENCE:

REMARKS:

Sample Interval (feet) From	Sample Interval (feet) To	Lithologic Interval (feet) From	Lithologic Interval (feet) To	Headspace Reading (units)	Spoon Blows	Recovery	Classification of Material
NA	NA	0	6	NA	NA	NA	Gravel fill.
NA	NA	6	22	NA	NA	NA	Orange-brown, fine to medium sand/trace silt.
NA	NA	22	35	NA	NA	NA	Orange-white coarse sand with thin layers of gray, white silty clay.
NA	NA	35	48	NA	NA	NA	Gray clay with wood; some silt.
NA	NA	48	59	NA	NA	NA	Red-white variegated clay.
NA	NA	59	61.5	NA	NA	NA	Gray clay with some gravel, silt and coarse sand.
NA	NA	61.5	68.5	NA	NA	NA	Dark gray clay with silt; trace coarse sand.
NA	NA	68.5	85	NA	NA	NA	Yellow-green silty clay with trace sand.
NA	NA	85	96	NA	NA	NA	Fine-medium brown sand w/little white & red clay & silt.
NA	NA	96	108	NA	NA	NA	Red and white silt and clay.
NA	NA	108	113	NA	NA	NA	Brown fine to medium sand with mica.
NA	NA	113	124	NA	NA	NA	White medium to coarse sand with mica; some gravel.
NA	NA	124	126.5	NA	NA	NA	White clay.

TETRA TECH INC.
WELL DRILLING LOG

PERMIT NO.
SHEET: 1 of 1

PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: BW-2	DATE(S) DRILLED: 5/2/94-5/5/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 40'; 10"40' to 125'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 125'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 125'-105'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 105'- +3' above ground
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 125'-100'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 95'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 100'-95'
DEVELOPMENT METHOD: Air Surging/Jetting TIME: 75 minutes	ESTIMATED YIELD: 35 gpm
STATIC WATER DEPTH: DATE: 5/06/94	REFERENCE:

REMARKS:

Sample Interval (feet)		Lithologic Interval (feet)		Headspace Reading (units)	Spoon Blows	Recovery	Classification of Material
From	To	From	To				
NA	NA	0	6	NA	NA	NA	Brown fine to medium sand w/silt.
NA	NA	6	12	NA	NA	NA	White medium to coarse sand with some silt
NA	NA	12	16	NA	NA	NA	Fine to medium brown sand with silt.
NA	NA	16	23.5	NA	NA	NA	Coarse brown sand with silt [illegible]ne gravel.
NA	NA	23.5	25	NA	NA	NA	Orange-red, gray clay with some sand.
NA	NA	25	35	NA	NA	NA	Gray clay, with silt; thin iron ore layer at 30.5'.
NA	NA	35	55	NA	NA	NA	Red/white variegated clay.
NA	NA	55	62.5	NA	NA	NA	Gray clay with little silt.
NA	NA	62.5	63.5	NA	NA	NA	Iron ore and yellow silty clay.
NA	NA	63.5	75	NA	NA	NA	Yellow-brown silty clay.
NA	NA	75	80	NA	NA	NA	White silty clay; trace fine sand.
NA	NA	80	85	NA	NA	NA	Brown very fine sand, trace silt.
NA	NA	85	87	NA	NA	NA	Orange-brown, fine to medium sand; trace silt.
NA	NA	87	105	NA	NA	NA	Red, white, yellow silt.
NA	NA	105	113	NA	NA	NA	Brown fine to coarse sand; trace silt.
NA	NA	113	125	NA	NA	NA	White medium to coarse sand with some gravel.
NA	NA	125	126	NA	NA	NA	White clay.

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TETRA TECH INC.
WELL DRILLING LOG

PERMIT NO.
SHEET: 1 of 1

PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: BW-3	DATE(S) DRILLED: 5/11/94-5/18/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 32'; 10" to 135'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 135'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 135'-50'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 50'- +3' above ground
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 135'-47'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 44'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 47'-44'
DEVELOPMENT 'HOD: Surging/Air Lifting TIME: 180 minutes	ESTIMATED YIELD: 25 gpm
STATIC WATER DEPTH: DATE: 6/06/94	REFERENCE:
REMARKS:	

SAMPLE INTERVAL (feet)		LITHOLOGIC INTERVAL (feet)		HEADSPACE READING (units)	SPOON BLOWS	RECOVERY	CLASSIFICATION OF MATERIAL
From	To	From	To				
NA	NA	0	20.5	NA	NA	NA	Organic matter, fine to coarse sand with some silt and gravel.
NA	NA	20.5	29.5	NA	NA	NA	Gray silty clay.
NA	NA	29.5	50	NA	NA	NA	Red/white clay.
A	NA	50	120	NA	NA	NA	Brown, very fine to medium sand.
NA	NA	120	128	NA	NA	NA	Gray/black coarse sand.
NA	NA	128	133	NA	NA	NA	White-yellow silt.
NA	NA	133	137	NA	NA	NA	White/red clay.

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 1 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453
DRILLING CONTRACTOR Warren George, Inc.		ELEVATION 40.16' amsl
PURPOSE Monitoring Well Installation -- Phase II		DATUM land surface

GROUNDWATER					CASING	SAMPLE	CORE
DATE	TIME	DEPTH	CASING	TYPE	Mud Rot.	Split Spoon	N/A
				DIAMETER	8"	2"	
				WEIGHT		300#	
				FALL		30"	

DATE STARTED 3-11-86
DATE FINISHED 3-18-86
DRILLER T. Tirro
INSPECTOR Glen Combes/Duane Wanty

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
		S-1	3 3 4 6	MH		Rd Br & Gr $&C; iron staining	Rec = 1.2 Moist
5		S-2	3 4 4 4	MH		Rd Br & Gr Cy$; iron staining	Rec = 1.5 Moist
						Red Brown SILT and CLAY; iron staining	
10		S-3	3 2 3 4	CH		Gr & Rd Br C&$; seam Lt Gr $; iron staining	Rec = 1.8 Moist
						Driller States G @ 13'-15' (COLUMBIA)	
15		S-4	3 4 5 7	CL		0-0.2' mf(+)G (UPPER POTOMAC) 0.2-0.5 Rd Br C&$ t(-), cS, t(-)mG; iron staining	Rec = 0.5 Moist
20							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 2 OF 8
CLIENT DNREC - State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
20		S-5	5 5 8 9	CH		Gr& Br $yC; frqt pkts Gr $&C; variegated	Rec = 1.1 Moist
25		S-6	3 4 5 6	CH		Gr & Br $yC; variegated	Rec = 0.5 Moist
30		S-7	4 5 7 9	CH		Gr & Rd $yC t(-), mS; occ pkts Gn Br C&$	Rec = 1.3 Moist used 3" spoon
35		S-8	3 3 8 13	CH		Gr & Rd & Yw C&$; variegated	Rec = 1.5 Moist used 3" spoon
40		S-9	3 5 8 11	CH		Rd & Gr C&$ t(-), mS; variegated	Rec = 1.6 Moist used 2" spoon
45							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 3 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
45		S-10	5 6 10 10	CH		Rd & Gr $yC; occ pkts mf(-)S; variegated	Rec = 1.5 Moist used 2" spoon
50		S-11	3 4 6 7	CH		Gr & Rd $yC t(-), mS; variegated	Rec = 1.6 Moist used 2" spoon
						Gray and Red CLAY and SILT trace(-), medium SAND; variegated	
55		S-12	5 5 10 11	CH		Gr & Rd C&$ t(-), mS; occ pkt Gr Cy$; variegated	Rec = 1.8 Moist used 2" spoon
60		S-13	4 5 7 8	CH		Rd & Gr C&$; lyr Gr$; occ pkt Gr Cy$; variegated	Rec = 2.0 Moist used 2" spoon
65		S-14	5 7 13 14	CH		Gr & Ppl & Gn Br C&$; pkt Gr $&C; variegated	Rec = 2.0 Moist used 2" spoon
70							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 4 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
70		S-15	4 6 12 9	MH		Gr Br $&C; variegated	Rec = 2.0 WET used 2" spoon
75		S-16	5 6 9 10	CH		Rd Br & Gn Br & Gr C&$; frqt prts Gr $; variegated	Rec = 2.0 Moist used 2" spoon
80		S-17	6 7 10 11	CH		Rd & Gr $yC; frqt prts Gr $	Rec = 2.0 Moist used 2" spoon
85		S-18	9 50/.3	MH		Gr $&C; silt nodules	Rec = 0.9 Moist used 2" spoon
90		S-19	6 8 11 15	CH SP		0-1.3' Dk Gr C&$; frqt seams Gr Cy$ 1.3'-2.0' Gr vfS, s$	Rec = 2.0 WET used 2" spoon
95							

DUNN GEOSCIENCE CORPORATION
LATHAM, NEW YORK (518) 783-8102

TEST BORING LOG

BORING NO. DGC-10d

SHEET 5 **OF** 8

PROJECT Delaware Sand and Gravel Landfill RI

CLIENT DNREC, State of Delaware

JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
95		S-20	9 7 11 12	CH SM		0-1.3' Dk Gr C&$, frqt seam Dk Gr Cy$ 1.3-2.0' Dk Gr vf S, l(+)$; frqt prts Dk Gr C&$	Rec = 2.0 WET used 2" spoon
100		S-21	5 6 8 15	SP		Dk Gr vf S, l(-)$, frqt seams Dk Gr C&$	Rec = 2.0 WET used 2" spoon
105		S-22	6 7 11 12	MH SM		0-0.7' Gr $&C; frqt prts Gr C&$ 0.7-2.0' Gr vfS, s$; occ seams Gr $&C	Rec = 2.0 WET used 2" spoon
110			5 9 13 50	SP		0-0.2 Gr C&S 0.2-2.0 Rd & Yw & Or vfS, l$; frqt seams Lt Gr $yC; occ seam iron stone; occ lyr Rd & Gr C&$; iron staining	Rec = 2.0 Moist used 2" spoon
115			32 23 12 12	SP		Yw & Or & Wh f S; seam Lt Gr $yC	Rec = 1.0 WET used 2" spoon
						<u>Yellow and Gray fine SAND; layers Gray SILT and CLAY</u>	
120							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 6 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
120		S-25	10 14 15 17	CH		Lt Gr & Rd $yC; occ pkt Lt Gr $&C; variegated	Rec = 2.0 Moist used 2" spoon
						Light Gray and Red Silty CLAY; variegated	
125		S-26	6 15 37 50	CH SP		0-0.7' Rd & Gr & Yw $yC; variegated 0.7-1.5 Or & Yw & Lt Gr vf S, l(-)$; occ prts Lt Gr C	Rec = 1.5 used 2" spoon
130		S-27	16 19 23 20	SP		Lt Gr Wh fS; low angle bedding	Rec = 1.3 WET 300# hammer
135		S-28	13 15 18 17	SP		Lt Gr Wh c(-)m(-)f(+)S; planar bedding; lyr Yw cmS at bottom	Rec = 1.4 WET 300# hammer
140		S-29	13 21 25 22	SP		Lt Gr & Lt Or m(-)f(+)S, t Cy$; planar and low angle bedding	Rec = 1.2 WET 300# hammer
145							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 7 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
145						Light Gray fine SAND, trace Clayey SILT	Switched to 10' sampling; approved by WJM
150		S-30	25 28 37 50/.4	SM		Lt Gr vfS; lyrs Lt Gr Wh C	Rec = 1.7 WET 300# hammer
155							
160		S-31	36 50/.4	SP		Lt Gr & Lt Gn & Yw f S, t (-) Cy$	Rec = 0.5 WET 300# hammer
165							
170						(UPPER POTOMAC) ------?----?-----?-----?-----?-----?--- (MIDDLE POTOMAC)	

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 8 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
170		S-32	5 10 12 15	CL CH		0-1.1' Gr & Yw & Rd C&$ 1(-), c(-)m(-) f(+)S, t(-) mfG -----171.1 feet----- 1.1-2.0' Dk Gr & Rd C; variegated	Rec = 2.0 Moist 300# hammer
						Gray and Red Silty CLAY; variegated	
						E.O.B. 172'	
						Lockable Steel Protective Casing	
						Grout (cement and bentonite)	0-123'
						Bentonite Seal	123-126'
						Sand Pack (Morie #1)	126-140'
						Sand Fill and Cuttings	140-172'
						Stick up (PVC)	1.95'
						Riser (sch. 40, flush joint, 4"ID PVC)-	+1.95 - 128'
						Screen (sch.40, flush joint, 4"ID, 10 slot PVC)	128 - 138'

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-10s

PROJECT	Delware Sand and Gravel Landfill RI		DGC-10s
CLIENT	DNREC, State of Delaware	SHEET 1 OF 1	
DRILLING CONTRACTOR	Warren George, Inc.	JOB NO.	560-2-4453
PURPOSE	Monitoring Well Installation - Phase II	ELEVATION	40.24' amsl

GROUNDWATER					CASING	SAMPLE	CORE		
DATE	TIME	DEPTH	CASING	TYPE	Mud Rot	N/A	N/A	DATUM	land surface
								DATE STARTED	3-18-86
				DIAMETER	8"			DATE FINISHED	3-20-86
				WEIGHT				DRILLER	Tony Tirro
				FALL				INSPECTOR	Duane A. Wanty

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
							no sampling
						E.O.B. 115'	
						Lockable steel protective casing	
5						Grout (cement and bentonite)	0-88'
						Bentonite seal	88-91'
						Sand pack (Morie #1)	91-115'
10						Stick up (PVC)	2.04'
						Riser (sch. 40, flush joint, 4" ID PVC)	+2.04 - 93'
						Screen (sch. 40, flush joint, 4" ID, 10 slot PVC)	93 - 113'
15							
20							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d

PROJECT	Delaware Sand and Gravel Landfill RI	
CLIENT	DNREC, State of Delaware	SHEET 1 OF 8
DRILLING CONTRACTOR	Warren George, Inc.	JOB NO. 560-2-4453
PURPOSE	Monitoring Well Installation - Phase II	ELEVATION 37.33' amsl

GROUNDWATER					CASING	SAMPLE	CORE	
DATE	TIME	DEPTH	CASING	TYPE	Mud Rot.	SS	N/A	DATUM land surface
								DATE STARTED 3-3-86
				DIAMETER		2"		DATE FINISHED 3-7-86
				WEIGHT		140#&300#		DRILLER Tony Tirro
				FALL		30"		INSPECTOR Duane Wanty

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
		S-1	2 2 3 5	CH		0-0.2 Dk Br Cy$ [A-Horizon; topsoil] 0.2-0.75 Br & Or Br $yC+, cmS, +fG	Rec = 0.75' Moist
						Brown and Orange Brown CLAY & SILT trace, course to fine SAND, trace fine GRAVEL	
5		S-2	7 11 12 13	CL		Br & Or Br $&Ct, cmfS, tfG	Rec = 1.5' Moist
						Driller noted thin Gravel layer at 8'	
10		S-3	14 18 16 15	SW		Or c(-) m(-)f(±)S, l Cy$, t(±)mfG	Rec = 1.2' Moist
						Orange coarse to fine SAND, little Clayey SILT, and coarse to fine GRAVEL	
15		S-4	20 18 7 8	GW		Or cmfG a(+), mfS, l Cy$	Rec = 0.1' (uncohesive) WET
						(COLUMBIA) Driller noted clay at 18' (UPPER POTOMAC)	
20							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 2 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
20		S-5	6 12 19 22	CH		Rd & Lt Gr Wh C; variegated	Rec = 0.3' Moist
25		S-6	4 4 9 9	CH		Rd & Lt Gr Wh C; variegated	Rec = 1.1' Moist
30		S-7	6 8 13 11	CH		Rd & Lt Gr Wh C; variegated	Rec = 1.5' Moist
35		S-8	11 16 30 23	CH		Lt Gr Wh SyC	Rec = 1.5' Moist
40		S-9	9 14 20 24	CH		Rd & Lt Gr Wh C; variegated Red & Light Gray White CLAY; variegated	Rec = 1.8' Moist
45							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 3 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 360-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
45		S-10	12 19 29 30	CH		Rd & Lt Gr Wh & Yw Gn C; variegated	Rec = 1.8' Moist
50		S-11	15 18 28 28	CH		Lt Gr Wh & Yw Gn C; variegated	Rec = 1.8' Moist
55		S-12	19 24 25 38	CH		Lt Gr Wh & Br & Rd & Yw Gn C; variegated	Rec = 2' Moist
60		S-13	3 5 9 8	CH		Gr C	Rec = 2' Moist 300 lb. hammer
65		S-14	6 6 8 28	CH SM		0-1.6' GrC 66.6' 1.6'-2.0' Gr vf S, a Cy$	Rec = 2.0' WET 300#

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 4 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
70		S-15	10 21 32 33	ML		Lt Gr vf S, l(+)Cy$; lyrs Dk Gr $&C	Rec = 1.5' Moist
						Light Gray very fine SAND, and Clayey SILT	
75		S-16	22 17 20 18	SM		Lt Gr vf S, s(-)Cy$	Rec = 1.2' WET 300#
80		S-17	10 17 19 17	ML		Md Gr & Lt Gr $&C l,vf S; lyr $yC; lignite	Rec = 2.0' WET 300#
85		S-18	7 9 10 15	CH		Rd & Gr & Yw Gn C; variegated	Rec = 1.8' WET 300#
90		S-19	7 8 14 13	ML		Gr $&C	Rec = 2.0' WET
						Red & Gray SILT and CLAY	

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 5 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
95		S-20	5 4 6 8	CH		Alt lyrs Gr C and Gr Cy$	Rec = 2.0' WET 300#
100		S-21	4 3 10 12	SP		Gr vfS, a Cy$; lyrs Dk Gr C	Rec = 1.2' WET 300#
105		S-22	9 16 13 15	CH SP		0-0.2' Gr C 0.2-1.0' Yw vfS 1.0-1.8' Rd Or vfS	Rec = 1.8' WET 300#
110		S-23	10 19 30 18	SP		Lt Or & Lt Tn vfS; t(+) Cy$	Rec = 1.2' WET 300#
115		S-24	8 9 10 10	SP		Or & Lt Rd vfs, l Cy$; lyrs Lt Gr Wh C	Rec = 1.7' WET 300#
120							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 6 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
120		S-25	50	SP		Lt Tn fS, t Cy$	Rec = 0.5' WET 300#
125		S-26	50	SP		Lt Tn fS, t Cy$	Rec = 0.5' WET 300#
130		S-27	10 11 26 34	SP		Lt. Tn & Or & Lt Gr Wh fS, t Cy$; lyr Lt Gr Wh C	Rec = 1.6' WET 300#
135		S-28	8 19 27 36	CH SW		0-1.1 2.0 Lt Gr Wh C	Rec = 2.0' WET 300#
140		S-29	42 50	SW		Lt Gr Wh & Or cmf S, t(-)Cy$, t mfG	Rec = 0.7' WET 300#
						Light Gray White and Tan coarse (-) to fine (+) SAND, trace Clayey SILT	

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill, RI		SHEET 7 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSIFICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
145		S-30	19 17 21 19	SW		Lt Gr Wh & Gr cmfS, t Cy$, t fG; lyrs Wh C at bottom	Rec = 1.3' WET 300#
150		S-31	13 6 9 18	SP		Lt Gr Wh & Or & Lt Rd & Yw mfS, t (-) Cy$	Rec = 1.6' WET 300#
155		S-32	28 50	SP		Lt Gr Wh fS, t Cy$	Rec = 0.7' WET 300#
160		S-33	22 50	SP		Lt Gr Wh fS, t Cy$	Rec = 0.8' WET 300#
165		S-34	20 23 50	SP		Lt Gr Wh & Lt Yw mfS, t Cy$	Rec = 1.2' WET 300#
170							

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11d
PROJECT Delaware Sand and Gravel Landfill RI		SHEET 8 OF 8
CLIENT DNREC, State of Delaware		JOB NO. 560-2-4453

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
170		S-35	50	SW		Lt Gr Wh cmf (+) S, + Cy$, t (-) fG	Rec = 0.3' WET 300#
175		S-36	27 37 50	SP		Or Br & Lt Gr Wh & Yw fS, t Cy$ Driller hit very hard layer (basal gravel?) at 177-178.5' (UPPER POTOMAC) ------------------------------ (MIDDLE POTOMAC)	Rec = 1.1' WET 300#
180		S-37	12 16 20 21	CH		Rd & Lt Gr Wh C; Variegated	Rec = 1.6' WET 300#
						E.O.B. 180' (sampled to 182') lockable	
						Protective steel casing	
						Grout (cement and bentonite)	0-100'
						Bentonite seal	100-103'
						Sand pack (Morie #1)	103-115'
						Sand fill and cuttings	115-182'
						Stick up (PVC)	1.75'
						Riser (sch. 40, flush joint, 4" ID PVC	+1.75 - 105'
						Screen (sch. 40, flush joint, 4" ID, 10 slot PVC)	105 - 115'

DUNN GEOSCIENCE CORPORATION LATHAM, NEW YORK (518) 783-8102	TEST BORING LOG	BORING NO. DGC-11s

PROJECT Delaware Sand & Gravel Landfill RI	
CLIENT DNREC, State of Delaware	SHEET 1 OF 1
DRILLING CONTRACTOR Warren George, Inc.	JOB NO. 560-2-4453
PURPOSE Monitoring Well Installation -- Phase II	ELEVATION 37.18' amsl

GROUNDWATER					CASING	SAMPLE	CORE	DATUM Land Surface
DATE	TIME	DEPTH	CASING	TYPE	Mud Rot	N/A	N/A	DATE STARTED 3/7/86
				DIAMETER	8"			DATE FINISHED 3/7/86
				WEIGHT				DRILLER Tony Tirro
				FALL				INSPECTOR Duane A. Wanty

DEPTH FT.	CASING BLOWS	SAMPLE NUMBER	BLOWS ON SAMPLE SPOON PER 6"	UNIFIED CLASSI-FICATION	GRAPHIC LOG	IDENTIFICATION	REMARKS
						E.O.B. 82'	
						Lockable protective steel casing	
						Grout (cement bentonite)	0 - 65'
						Bentonite Seal	65 - 68'
						Sand Pack (Morie #1)	68 - 82'
						Stick-up (PVC)	1.72'
5						Riser (Sch 40, flush joint, 4"ID PVC)	+1.72 - 70'
						Screen (Sch 40, flush joint, 4"ID 10-slot PVC)	70 - 80'
10							
15							
20							

Test hole #18 11-13-72 **Dc 24-21**

next to RW-2

Depth	Description
0-2	yellow-brown medium-coarse sand (fill)
2-3	black sandy-tarry layer
3-4.5	yellow-brown v. coarse rounded gravel (to 1') w/ some coarse sa
UPC 4.5-8	red, white & yellow stiff clay
8-11	yellow-yellow brn & red stiff clay
11-25	red & white clay
25-34	light gray dense silty clay and yellow-gray clay
UPA 34-39	buff fine-fine medium sand w/ thin stringers of white clay or silty clay and thin layers of ironstone
39-43	iron layer on top of white clay-silty clay
dC 43-47	gray-dark gray clay
47-52	buff fine sand w/ an overlying layer of ironstone
52-54	white silt
54-75	buff fine sand, mostly clean, but probably w/ some iron cementa as drilling was tough
PA 75-80	orange medium-coarse sand w/ interbedded ironstone layers
80-90	orange -whitish orange () coarse sand w/ interbedded ironstone layers
90-95	buff-orange fine sand
95-96	orange & white sandy clay
97-99	white & orange coarse-v. coarse sand
99-102	white silty clay or clayey silt
102-128	orange-buff fine sand w/ occasional thin stringers of white:
128-131	orange coarse sand w/ ironstone layers
131-138	yellowish & white silty, v. fine sandy clay or clayey silt
MPC 138-141	red & white clay
141-145	red clay

Test hole #18 (cont.)

Comments: The uppermost sand sequences, a fine sand w/ clay stringers (34-39) and a fine sand (47-52) have the highest apparent resistivities in the entire section. The generally coarser sand sequences — which contain no more clay — had apparent resistivities up to 200 Ω-m, and usually 100 Ω-m less that the upper fine sands. Thus, it appears that if the fluid in the upper sands is uncontaminated water (~100 μmho cm^{-1} conductance), then the deeper sands have a fluid whose conductivity may be in the 500-1000 μmho cm^{-1} conductivity range.

TETRA TECH INC. **WELL DRILLING LOG**	PERMIT NO. SHEET: 1 of 1
PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: MW-22N	DATE(S) DRILLED: 6/07/94-6/14/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 55'; 10" to 159'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 159'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 159'-139'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 139'- +3' above grade
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 159'-134'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 128'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 134'-128'
DEVELOPMENT METHOD: Surging/Air Lifting TIME: 180 minutes	ESTIMATED YIELD: 50 gpm
STATIC WATER DEPTH: DATE: 7/05/94	REFERENCE:
REMARKS:	

SAMPLE INTERVAL (feet)		LITHOLOGIC INTERVAL (feet)		HEADSPACE READING (units)	SPOON BLOWS	RECOVERY	CLASSIFICATION OF MATERIAL
From	To	From	To				
NA	NA	0	19.5	NA	NA	NA	Orange-brown fine to medium sand with some silt and gravel.
NA	NA	19.5	30	NA	NA	NA	Brown/black fine to coarse sand with gravel.
NA	NA	30	50	NA	NA	NA	Fine to medium brown sand, little gravel.
NA	NA	50	52	NA	NA	NA	Iron ore.
NA	NA	52	72	NA	NA	NA	White-red clay.
NA	NA	72	82	NA	NA	NA	Fine to coarse sand and gravel with iron ore seams.
NA	NA	82	128	NA	NA	NA	Red, white, brown silty clay with a few small fine sand and iron ore lenses.
NA	NA	128	153	NA	NA	NA	White, silty clay with small iron ore and fine sand lenses.
NA	NA	153	159	NA	NA	NA	White fine to coarse sand and gravel.
NA	NA	159		NA	NA	NA	White clay.

TETRA TECH INC.
WELL DRILLING LOG

PERMIT NO.
SHEET: 1 of 1

PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: MW-26N	DATE(S) DRILLED: 6/28/94-6/30/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 32'; 10" to 168'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 168'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 168'-108'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 108'- +3' above grade
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 168'-105'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 101'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 105'-101'
DEVELOPMENT METHOD: Surging/Air Lifting TIME: 180 minutes	ESTIMATED YIELD: 100 gpm
STATIC WATER DEPTH: DATE: 7/05/94	REFERENCE:
REMARKS:	

SAMPLE INTERVAL (feet)		LITHOLOGIC INTERVAL (feet)		HEADSPACE READING (units)	SPOON BLOWS	RECOVERY	CLASSIFICATION OF MATERIAL
From	To	From	To				
NA	NA	0	9	NA	NA	NA	Brown/gray clay.
NA	NA	9	15	NA	NA	NA	Orange-brown fine to coarse sand; some silt.
NA	NA	15	21	NA	NA	NA	Orange-brown fine to coarse sand.
NA	NA	21	25	NA	NA	NA	Brown-gray silty clay.
NA	NA	25	29	NA	NA	NA	Red, white, brown silty clay with some fine sand.
NA	NA	29	57	NA	NA	NA	Red, white, gray clay.
NA	NA	57	78	NA	NA	NA	Gray, clay with some fine sand, iron ore, wood.
NA	NA	78	94	NA	NA	NA	White and light gray clay.
NA	NA	94	110	NA	NA	NA	Gray clay.
NA	NA	110	126	NA	NA	NA	Fine to medium tan sand.
NA	NA	126	166	NA	NA	NA	Fine to coarse tan sand with white clay seams.
NA	NA	166		NA	NA	NA	White and gray clay.

f:\wpdata\0151\misc\wl-dril.log

TELEPHONE 302/337-8254

Delmarva Drilling Co., Inc.

P. O. BOX 188 BRIDGEVILLE, DELAWARE 19933

Water Well Contractors

CUSTOMER Roy F. Weston, Inc. #28 JOB 1604

ADDRESS New Castle DATE 3-14-73

LOCATION Gravel Pit

FEET FROM GROUND SURFACE 0 TO........	Test hole WELL LOG
0 - 26	Stones gravel clay sand, pea gravel
26 - 36	Clay
36 - 37	Iron ore layers (left a ledge in hole)
37 - 52	Clay and sand layers
52 - 58	Clay, gray
58 - 76	Sand with clay layers
76 - 88	Red and gray clay with little sand
88 - 90	Fine to coarse sand with little clay layers
90 - 112	Fine to coarse sand
112 - 118	Fine to med sand with gray clay layers
118 - 119	Red and gray clay
119 - 1[illegible]	Fine to med sand with clay layers
	T. D. 13[illegible]

WELL NO. [illegible]

HRS. PUMPED [illegible]

CAPACITY G.P.M. [illegible]

STATIC LEVEL [illegible]

PUMPING LEVEL

SPECIFIC CAPACITY

PUMPED WITH

DEPTH OF CEMENT GROUT

DEPTH GRAVEL PACKED

DIAMETER OF WELL [illegible]

SLOT SIZE .016

DRILLING MACHINE NO. [illegible] 2

DRILLER [illegible]

GRAVEL [illegible]

BAGS OF CEMENT [illegible]

DATE WELL COMPLETED [illegible]-73

DRILLER'S HELPER [illegible]

DEPT. OF WELL [illegible]

TYPE OF CASING PVC - [illegible]

LENGTH OF CASING [illegible]

DISTANCE TO TOP OF SCREEN [illegible]

TYPE SCREEN PVC

SIZE OF SCREEN [illegible]

WELL DRILLER SIGNATURE

TELEPHONE 302/337-8254

Delmarva Drilling Co., Inc.

P. O. BOX 188 BRIDGEVILLE, DELAWARE 19933

Water Well Contractors

CUSTOMER: Roy F. Weston, Inc. JOB: 1604

ADDRESS: New Castle, Dela DATE: 3-16-73

LOCATION: Gravel pit GS=15 # 29

FEET FROM GROUND SURFACE 0 TO...........	WELL LOG
0 - 5	Clay and sand mixed
5 - 9	Blue clay
9 - 19	Fine to coarse sand with gravel
19 - 24	Gray clay
24 - 33	Gray and red clay with sand layers
33 - 65	Fine to coarse tan sand
65 - 72	Fine to coarse tan sand with clay layers
72 - 81	Fine to med. sand with clay layers
81 - 110	Fine to coarse tan sand with white clay layers
110 - 115	White clay with little sand
115 - 126	Brown clay
	T. D. [illegible] 126'

GROUND — TOTAL DEPTH - FT. — CASING — SCREEN

WELL NO.	DIAMETER OF WELL 6"	DEPT. OF WELL 126'
HRS. PUMPED	SLOT SIZE	TYPE OF CASING [illegible]
CAPACITY G.P.M.	DRILLING MACHINE NO. [illegible]	LENGTH OF CASING [illegible]
STATIC LEVEL	DRILLER [illegible]	DISTANCE TO TOP OF SCREEN [illegible]
PUMPING LEVEL	GRAVEL	TYPE SCREEN
SPECIFIC CAPACITY	BAGS OF CEMENT	SIZE OF SCREEN [illegible]
PUMPED WITH	DATE WELL COMPLETED [illegible]	
DEPTH OF CEMENT GROUT	DRILLER'S HELPER [illegible]	[illegible] WELL DRILLER SIGNATURE
DEPTH GRAVEL PACKED [illegible]		

Delmarva Drilling Co., Inc.

P. O. BOX 188 • BRIDGEVILLE, DELAWARE 19933

Water Well Contractors

CUSTOMER Roy F. Weston Inc. JOB 1604

ADDRESS New Castle, Dela. DATE 3/23/73

LOCATION Gravel pit #31

FEET FROM GROUND SURFACE 0 TO..........	WELL LOG
0-5	Fill material
5-10	Green and Brown Clay
10-22	Fine to course tan sand with gravel
22-54	White clay, ~~rand~~ red clay sand layers fine to med.
54-56	Fine to med. sand with iron ore layers
56-63	Fine to med. sand with clay layers
63-74	Fine to course sand with clay ~~x~~layers
74-81	Fine to course sand
81-93	Fine sand with white clay layers
93-100	Fine to course sand with clay layers
~~[illegible]~~	
100-110	Fine sand with white clay layers
110-120	Brown clay
	T.D.W. 116'
	Feeder tube 1' above-22'

GROUND — TOTAL DEPTH - FT. — CASING — SCREEN

WELL NO. #31	DIAMETER OF WELL 6"	DEPT. OF WELL 116'
HRS. PUMPED [illegible]	SLOT SIZE .016	TYPE OF CASING steel-P.V.C.
CAPACITY G.P.M. [illegible]	DRILLING MACHINE NO. [illegible]	LENGTH OF CASING 59'
STATIC LEVEL [illegible]	DRILLER Pierson	DISTANCE TO TOP OF SCREEN 59' -1[illegible]
PUMPING LEVEL —	GRAVEL [illegible]	TYPE SCREEN P.V.C.
SPECIFIC CAPACITY —	BAGS OF CEMENT 12	SIZE OF SCREEN 6"
PUMPED WITH [illegible]	DATE WELL COMPLETED 3/27/73	
DEPTH OF CEMENT GROUT [illegible]	DRILLER'S HELPER Wallace	Pierson
DEPTH GRAVEL PACKED [illegible]		WELL DRILLER SIGNATURE

TETRA TECH INC.
WELL DRILLING LOG

PERMIT NO.
SHEET: 1 of 1

PROJECT: Army Creek	PROJECT NO. 0151-14
WELL DESIGNATION: MW-38N	DATE(S) DRILLED: 5/23/94-5/25/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 47'; 10" to 132'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 132'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 132'-72'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 72'- +3' above grade
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 132'-69'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 66'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 69'-66'
DEVELOPMENT METHOD: Surging/Air Lifting TIME: 180 minutes	ESTIMATED YIELD: 45 gpm
STATIC WATER DEPTH: DATE: 6/08/94	REFERENCE:
REMARKS:	

SAMPLE INTERVAL (feet)		LITHOLOGIC INTERVAL (feet)		HEADSPACE READING (units)	SPOON BLOWS	RECOVERY	CLASSIFICATION OF MATERIAL
From	To	From	To				
NA	NA	0	38	NA	NA	NA	Brown fine to coarse sand with gravel.
NA	NA	38	76	NA	NA	NA	Gray, brown, yellow, white silty clay with iron ore seams.
NA	NA	76	116	NA	NA	NA	Very fine to medium orange-brown sand.
NA	NA	116	126	NA	NA	NA	White medium to coarse sand with gravel.
NA	NA	126	132	NA	NA	NA	Brown fine to coarse sand.
NA	NA	132	133	NA	NA	NA	Iron ore seam.
NA	NA	133	136	NA	NA	NA	White clay.

TETRA TECH INC. **WELL DRILLING LOG**	PERMIT NO. SHEET: 1 of 1
PROJECT: Army Creek	PROJECT NO. 0151-06
WELL DESIGNATION: MW-49N	DATE(S) DRILLED: 6/20/94-6/24/94
DRILLING CONTRACTOR: Walton Corporation	DRILLING METHOD: Mud Rotary
BORING DIAMETER: 14" to 57'; 10" to 158'	SAMPLING METHOD: Drill Cuttings
SAMPLING INTERVAL: Continuous	TOTAL DEPTH: 158'
LOGGED BY: C. W. Geiger	
SCREENED SIZE AND MATERIAL: 4" Schedule 40 PVC, 0.020" slots	SCREENED INTERVAL: 158'-113'
CASING SIZE AND MATERIAL: 4" Schedule 40 PVC	CASED INTERVAL: 113'- +3' above grade
GRAVEL PACK SIZE: #2 Morie Sand	PACKED INTERVAL: 158'-109'
GROUT TYPE: Cement-Bentonite	GROUTED INTERVAL: 105'-0
GROUTING METHOD: Pressure	BENTONITE SEAL: 109'-105'
DEVELOPMENT METHOD: Surging/Air Lifting TIME: 180 minutes	ESTIMATED YIELD: 50 gpm
STATIC WATER DEPTH: DATE: 7/06/94	REFERENCE:
REMARKS:	

SAMPLE INTERVAL (feet)		LITHOLOGIC INTERVAL (feet)		HEADSPACE READING (units)	SPOON BLOWS	RECOVERY	CLASSIFICATION OF MATERIAL
From	To	From	To				
NA	NA	0	5	NA	NA	NA	Brown silty clay.
NA	NA	5	53.5	NA	NA	NA	Orange-brown, fine to coarse sand with some silt and gravel.
NA	NA	53.5	75	NA	NA	NA	Red, white, gray clay.
NA	NA	75	88	NA	NA	NA	White clay.
NA	NA	88	98	NA	NA	NA	Gray clay with small iron ore seams.
NA	NA	98	114	NA	NA	NA	Red, white, yellow clay interbedded with seams of fine tan sand and iron ore.
NA	NA	114	125	NA	NA	NA	Tan fine to medium sand with some lenses of clay and iron ore. lenses.
NA	NA	125	139	NA	NA	NA	Orange brown fine to coarse sand with gravel.
NA	NA	139	158	NA	NA	NA	White medium to coarse sand with gravel.
NA	NA	158		NA	NA	NA	White, red clay.

ACC 56-70
PARTIAL WELL LOGS

A.C. SCHULTES & SONS, INC.

SINGLE CASE WELL

GROUND LEVEL

WELL LOG	FEET FROM GROUND SURFACE	NAME OF OWNER
Brown sand	0 - 9	New Castle County
Yellow Clay	9' - 11'	Job # 18390
Sand stone	11' - 13'	Location Langollin Landfill
Silty, orange clay	13' - 17'	Well Monitor 56
Brown sand	17' - 18'	Hrs. Pumped BIEW 12 hou
Red & white clay	18' - 33'	Capacity G.P.M. 60
Fine, silty sand	33' - 50'	Static Level 29'-6"
Fine, white sand	50' - 58'	Pumping Level
Layers of white clay		Specific Capacity
White clay	58' - 70'	Diameter of Well 4"
White sand/ layers of	70' - 101'	Depth of Well (ground) 100'
clay		Length of Casing 75'
Red clay	101' - 105'	Distance to Top of Packer
		Type Screen PVC
		Size of Screen 4"
		Length of Screen 25'
		Top Screen Fitting couple
		Bottom Screen Fitting cap
		Blank NO
		Slot Size .020
		Drilling Machine No. D-3
		Driller Charlie Kramer
		Gravel #2
		Bags of Cement 15
		Date Well Completed 7-9-80

CASING

SCREEN

TOTAL DEPTH

Remark: Table approx. 3' above ground level

A.C. SCHULTES & SONS, INC.

SINGLE CASE WELL

WELL LOG	FEET FROM GROUND SURFACE
Brown clay	0 to 4
Brown sand	4 - 6
Gray clay	6 - 15
Brown sand	15 - 19
Sand stone	19-23
White clay	23 - 29
Brown sand/ layers clay	29 - 45
Red & White clay	45 - 63
Sand, silty/layers clay	63 - 76
White sand	76 - 81
Hard clay	81 - 89
Fine sand & mud	89 - 106
White clay	106 - 108
White sand	108 - 111
Red clay	111 - 118

NAME OF OWNER New Castle County

Job # 18390

Location Landfill

Well No. Monitor #58

Hrs. Pumped

Capacity G.P.M. 60

Static Level

Pumping Level

Specific Capacity

Diameter of Well 4"

Depth of Well (ground) 110'-0"

Length of Casing 65'-0"

Distance to Top of Packer

Type Screen PVC

Size of Screen 4"

Length of Screen 35'-0"

Top Screen Fitting Couple

Bottom Screen Fitting Cap

Back Yes - 10'-0"

Slot Size .020"

Drilling Machine No. D3

Driller Kramer

Gravel #2

Bags of Cement 15

Date Well Completed 7-8-80

... above ground level

TETRA TECH INC. - TEST BORING LOG Page 1 of 2

Project Name: Army Creek			Project No.: R0151-20
Project Location: New Castle De			
Test Boring No.: P-4		Date(s) Drilled: 12/111/02 to	Inspector: D. Neidigh
Drilling Contractor: A. C. Schultes		Drilling Method: MudRotary/Split Spoon	Driller: Dennis G
Surface Elevation (ft):		Groundwater Depth (ft):	Total Depth (ft):

Sample		Sample Depth (ft)			PID readings		Strata Depth (ft)				Blow Counts			
Time	No.	From	To	Recovery (inches)	Depth (ft)	PPM	From	To	Description of Materials	Moisture	0-6"	6-12"	12-18"	18-24"
							0	56	Orange brown sand with trace gravel. Gravel layer @ 24'					
									and 42' to 45'					
							56	70	Red & gray clay with tracefine sand					
1040	1	70	72	4					Dark gray clay withsome very fine sand	M				
1115	2	75	77	3					Same as above		130/4			
1153	3	80	82	2					Dark redesh brown sand, silt, clay		100	50/3		
124	4	85	87	6					Brown & gray sand trace fine gravel, little silt		132/2 *			
1300	5	90	92	3					Brown sand, little silt, trace fine gravel		150/3 *			
1400	6	95	97	1					Light brown bine to medium sand little silt		150/3 *			
1440	7	100	102	1					Same as above		150/2 *			
1540	8	105	107	1					Brown sand		172/4 *			
1630	9	110	112	6					Brown fine to coarse sand, little silt		154			
											70	100	100+	
940	10	115	117	8					light brown fine sand, trace silt					

Notes and comments

* At these locations the hammer was raised to the top of the mast and dropped 3 to 4 times to remove the accumlated sand and gravel that had fallen from the side walls of the borehole prior to driving the spoon for lithologic samples.

Moisture codes: D-dry, M-moist, W-wet, S-saturated

TETRA TECH INC. - TEST BORING LOG Page 2 of 2

Project Name: Army Creek			Project No.: R0151-20
Project Location: New Castle De			
Test Boring No.: P-4	Date(s) Drilled: 12/111/02 to		Inspector: D. Neidigh
Drilling Contractor: A. C. Schultes	Drilling Method: MudRotary/Split Spoon		Driller: Dennis G
Surface Elevation (ft):	Groundwater Depth (ft):		Total Depth (ft):

Sample		Sample Depth (ft)		Recovery (inches)	PID readings		Strata Depth (ft)		Description of Materials	Moisture	Blow Counts			
Time	No.	From	To		Depth (ft)	PPM	From	To			0-6"	6-12"	12-18"	18-24"
1053	11	120	122	4					light brown fine sand, trace silt		71	131	156	300'
1227	12	125	127	3					Brown fine sand and clay		17	17	100	200+
1357	13	130	132	1					White clay with little very fine sand		100	140/4	*	
1455	14	135	137	1					Same as above		100	150/3	*	

Notes and comments

Gig chatter and slow drilling 78' to 80'.

1015 taking water @ 100' to 105'

Moisture codes: D-dry, M-moist, W-wet, S-saturated

TETRA TECH INC. - TEST BORING LOG

Project Name: Army Creek			Project No.: R0151-20
Project Location: New Castle De			
Test Boring No.: P-5L	Date(s) Drilled: 11/27/02 to 11/30/02		Inspector: D. Neidigh
Drilling Contractor: A. C. Schultes	Drilling Method: Rotary/Split Spoon		Driller: Dennis G
Surface Elevation (ft):	Groundwater Depth (ft):		Total Depth (ft):

Sample		Sample Depth (ft)			PID readings		Strata Depth (ft)				Blow Counts			
Time	No.	From	To	Recovery (inches)	Depth (ft)	PPM	From	To	Description of Materials	Moisture	0-6"	6-12"	12-18"	18-24"
		0	12						Fine to medium sand and gravel					
		12	19						Sand & white clay					
		19	40						Fine to medium sand and gravel					
		40	70						Interbedded clay & sand					
		70	80						Medium sand					
		80	100						White & Red clay					
		100	115						Interbedded sand &clay					
		115	136						Fine to medium sand					
		136	180						yellow, red & gray glay					

Notes and comments

Moisture codes: D-dry, M-moist, W-wet, S-saturated

TETRA TECH INC. - TEST BORING LOG Page 1 of 2

Project Name: Army Creek		Project No.: R0151-10	
Project Location: New Castle De			
Test Boring No.: P-5U	Date(s) Drilled: 12/12/01 & 12/13/02	Inspector: E Scott	
Drilling Contractor: A. C. Schultes	Drilling Method: Mud Rotary/Split Spoon	Driller: Dennis G	
Surface Elevation (ft):	Groundwater Depth (ft):	Total Depth (ft):	

Sample		Sample Depth (ft)		Recovery (inches)	PID readings		Strata Depth (ft)				Blow Counts			
Time	No.	From	To		Depth (ft)	PPM	From	To	Description of Materials	Moisture	0-6"	6-12"	12-18"	18-24"
1020		50	53	N/A					Very rocky, minor red, yellow clay, gravel 1/4" to 2" consisting of quartz,					
									smoky quartz, gray sandstone sub-angular to sub-rounded. From cuttings					
1050		55		N/A					White clay. From cuttings					
1115		60	62	4		0	0	4	Very fine, very dense beige sand	M	90			
1130		65	67	4		0	0	4	Very fine, very dense beige sand	M	115			
1150		70	72	6		0	0	6	Very fine, dense sand with minor white & red clay mixed in	M	176			
1243	1	75	77	12		0	0	12	Very fine, dense sand with minor white & red clay mixed interfingers	M	900			
1320		80	82	2		0	0	2	White clay into hard red clay	M	95			
1345		85	87	12		0	0	12	Red and white clay to white-gray clay, very dense and very hard	M	102			
1410		90	92	8		0	0	8	Red & white clay to white sandy clay white sand layer 4" thick to white clay	M	92			
1430		95	97	4		0	0	4	Red and white clay; last 2" fine orange sand					

Notes and comments

Moisture codes: D-dry, M-moist, W-wet, S-saturated

TETRA TECH INC. - TEST BORING LOG

Project Name: Army Creek	Project No.: R0151-10
Project Location: New Castle De	
Test Boring No.: P-5U	Date(s) Drilled: 12/12/01 & 12/13/02	Inspector: E Scott
Drilling Contractor: A. C. Schultes	Drilling Method: Mud Rotary/Split Spoon	Driller: Dennis G
Surface Elevation (ft):	Groundwater Depth (ft):	Total Depth (ft):

Sample		Sample Depth (ft)		Recovery (inches)	PID readings		Strata Depth (ft)				Blow Counts			
Time	No.	From	To		Depth (ft)	PPM	From	To	Description of Materials	Moisture	0-6"	6-12"	12-18"	18-24"
1500		100	102	6		0	0	6	Medium gray/white sand, minor quartz pieces	M	114			
1536		105	107	6		0	0	6	Gray/white fine sand	M	100			
1610		110	112	3		0	0	3	White silt	M	100			
1215		115	117	6		0	0	6	Dense fine white sand	W	115			
1250		120	122	2		0	0	2	Red & white clay	W	83			
1310	2	130	132	12		0	0	12	Dense fine beige sand	W	80			

TETRA TECH INC. - TEST BORING LOG

Project Name: Army Creek	Project No.: R0151-20
Project Location: New Castle De	
Test Boring No.: P6	Date(s) Drilled: 2/4/02	Inspector: E Scott
Drilling Contractor: A. C. Schultes	Drilling Method: Rotary/Split Spoon	Driller: Dennis G
Surface Elevation (ft):	Groundwater Depth (ft):	Total Depth (ft): 117

Sample		Sample Depth (ft)		Recovery (inches)	PID readings		Strata Depth (ft)				Blow Counts			
Time	No.	From	To		Depth (ft)	PPM	From	To	Description of Materials	Moisture	0-6"	6-12"	12-18"	18-24"
1108	1	60	62	8		0			Red and gray very hard dense clay					
1115	2	65	67	12		0			Gray clay, very dense					
1148	3	70	72	12		0			Gray clay, soft ~2" to a dark gray clay, very hard, very dense					
1202	4	75	77	12		0			Gray clay, soft ~8" to a dark gray clay, very hard, very dense					
1210	5	80	82	12		0			Very dark hard dense gray clay					
1230	6	85	87	12		0			Dark gray clay. Had dense. Last 2" soft and broken by small wood pieces					
1242	7	90	92	8		0			Dark gray clay very dense					
1300	8	95	97	6		0			Fine tan sand	M				
1315	9	100	102	1		0			Fine tan sand	M				
1340	10	105	107	6		0			Medium sand, tan, heavy iron staining					
1410	11	110	112	6		0			Alternating gray clay and orange Iron-stianed sand lenses					
1435	12	115	117	8		0			Gray clay, soft					

Notes and comments

Moisture codes: D-dry, M-moist, W-wet, S-saturated

ACL RW-10 TO RW-14 WELL LOGS

A.C. SCHULTES & SONS, INC.

SINGLE CASE WELL

GROUND 8" LEVEL

WELL LOG	FEET FROM GROUND SURFACE	NAME OF OWNER
Brown sand	0 TO 9	New Castle County
Sand Stone	9 ' - 10'	Job # 18390
Red & white clay	10' - 21'	Location Langollen Landfil
White & tan clay	21' - 29'	Well No. RW # 10
Gray clay	29' - 33'	Hrs. Pumped 8
Sand white	33' - 60'	Capacity G.P.M. 508
Sand & gravel	60 ' - 79'	Static Level 31'-0"
Sand, layers of gravel	79' - 1-3'	Pumping Level 53'-0"
Hard, red clay	103' - 107'	Specific Capacity 25
White clay	107' - 112'	Diameter of Well 10"
Red clay	112' - 102.5'	Depth of Well (ground) 102'-0"
		Length of Casing 78'-0"
		Distance to Top of Packer (gr.)
		Type Screen P.V.C
		Size of Screen 10"
		Length of Screen 25'-0"
		Top Screen Fitting Couple
		Bottom Screen Fitting Cap
		Blank No
		Slot Size .030
		Drilling Machine No. D-3
		Driller Kramer
		Gravel #2
		Bags of Cement 100
		Date Well Completed 6-3-80

10" CASING

25'-0" STRAINER

102'-0" DEP

Rotary Table approx. 3' above ground level

ATTACHMENTS ASSOCIATED WITH REVISED SAP

(Note: new tables and attachments are being added as indicated below; therefore, subsequent tables and attachments will be renumbered in the revised SAP)

TABLES

TABLE 1
DATA QUALITY OBJECTIVES
ADDITIONAL INVESTIGATION ACTIVITIES
ARMY CREEK LANDFILL SUPERFUND SITE
NEW CASTLE, DELAWARE

Investigation Activity	Matrix	Number of Locations	Parameters of Interest	Frequency of Monitoring	Purpose/Objective of Activity
Groundwater Monitoring	Groundwater	5 existing wells and up to 6 new wells	Total and dissoved iron, manganese, and cobalt, and field parameters (see note 3 below)	Quarterly for one year	Collect definitive data to define nature and extent of contamination
	Groundwater	5 existing wells and up to 6 new wells	TCL VOCs + up to 20 TICs; and major cations and anions (see note 4 below)	Semi-annually in April and October for one year	Collect definitive data to define nature and extent of contamination and to evaluate cation/anion balance in groundwater
	Groundwater	15 existing wells and up to 6 new wells	PFAS	Once, coincident with annual Site-wide PFAS sampling (either April or October)	Collect definitive data to define nature and extent of contamination
Leachate	Leachate	Up to 10 existing gas vents	PFAS	Once, coincident with annual Site-wide PFAS sampling (either April or October)	Collect definitive data to define nature and extent of contamination
Surveying	NA	New well locations and existing well locations with survey discrepancies	Ground and top of PVC elevation (wells only), northings and eastings	Once, after installation of new wells	Collect definitive data to verify well elevations and provide location data for new well samples

Notes:

1. The Target Compound List (TCL) for VOCs is provided in Table 8.
2. The methodologies that will be used for analysis are listed in Tables 5 and 7.
3. Field parameters for groundwater monitoring include: pH, temperature, specific conductivity, turbidity, dissolved oxygen, and oxidation-reduction potential.
4. Major cations and anions include: calcium, magnesium, potassium, sodium, ammonia, nitrate, nitrite, sulfate, sulfide, chloride, and bicarbonate.
5. VOCs, metals, and cations/anions quality control samples were collected per matrix at the following frequency: 1 field duplicate per twenty primary samples; 1 MS/MSD pair per twenty primary + field duplicate samples; 1 rinsate blank per day per type of decontamination event where non-dedicated equipment is used. 1 trip blank per day when aqueous VOC samples were collected.
6. PFAS quality control samples were collected per matrix at the following frequency: 1 field duplicate per twenty primary samples; 1 MS/MSD pair per twenty primary + field duplicate samples; 1 rinsate blank per day per type of decontamination event where non-dedicated equipment is used. 1 trip blank per day when aqueous PFAS samples were collected.

TABLE 2
DECISION THRESHOLD / ACTION LEVEL
ADDITIONAL INVESTIGATION ACTIVITIES
ARMY CREEK LANDFILL SUPERFUND SITE
NEW CASTLE, DELAWARE

Investigation Activity - Goal	Matrix	Number of Locations	Parameters of Interest	Screening Values/Method	Decision Threshold / Action Level
Drilling - Collect qualitative data to assist in developing screen interval recommendations	Soil	Up to 6 borings	Lithology; PID readings; visual and/or olfactory evidence of impacts	PID readings > 10 ppmv; visual evidence of a sheen or impacts; petroleum and/or chemical odor	1) If the screening values are met or exceeded, then a monitoring well will be screened across the 10-foot interval with the highest PID readings and/or the most visual and/or olfactory evidence of impacts within the unit to be monitored (i.e., UPA upper sand or UPA lower sand). 2) If the screening values are NOT met, then a monitoring well will be screened across the coarsest-grained 10-foot interval within the unit to be monitored (i.e., UPA upper sand or UPA lower sand).
	Groundwater				
Groundwater Monitoring - Collect definitive data to define nature and extent of contamination	Groundwater	5 existing wells and up to 6 new wells	Total and dissoved iron, manganese, and cobalt, and VOCs	MCLs, SMCLs and RSLs	1) If the screening values are exceeded, then additional investigation and/or plume stability evaluation may be necessary. 2) If the screening values are NOT exceeded but are above method detection limits, then quarterly monitoring should be reduced to semi-annual monitoring. 3) If the parameters are not detected at monitoring locations, then discontinuation of monitoring at those locations should be considered.
			Major cations and anions	Cation/Anion Balance	1) If the cation/anion balance exceeds 20% difference, then additional monitoirng of cations and anions and consideration of other potential cations and/or anions for analysis should be performed. 2)If the cation/anion balance has between 10 and 20% difference, then additional monitoring of cations and anions should be performed. 3) If the cation/anion balance has less than 10% difference, then additional monitoring of cations and anions should not be necessary.
	Groundwater	15 existing wells and up to 6 new wells	PFAS	HAL; RSL	1) If the screening values are exceeded, then additional evaluation may be necessary. 2) If the screening values are NOT exceeded but are above method detection limits, then annual monitoring should be considered. 3) If the parameters are not detected at monitoring locations, then PFAS monitoring at those locations should be discontinued.
Leachate - Collect definitive data to define nature and extent of contamination	Leachate	Up to 10 existing gas vents	PFAS	HAL; RSL	1) If the screening values are exceeded, then additional evaluation may be necessary. 2) If the screening values are NOT exceeded, then PFAS monitoring at those locations should be discontinued.

Notes:

1. The Target Compound List (TCL) for VOCs is provided in Table 8.
2. The methodologies that will be used for analysis are listed in Tables 5 and 7.
3. Field parameters for groundwater monitoring include: pH, temperature, specific conductivity, turbidity, dissolved oxygen, and oxidation-reduction potential.
4. Major cations and anions include: calcium, magnesium, potassium, sodium, ammonia, nitrate, nitrite, sulfate, sulfide, chloride, and bicarbonate.
5. VOCs, metals, and cations/anions quality control samples were collected per matrix at the following frequency: 1 field duplicate per twenty primary samples; 1 MS/MSD pair per twenty primary + field duplicate samples; 1 rinsate blank per day per type of decontamination event where non-dedicated equipment is used. 1 trip blank per day when aqueous VOC samples were collected.
6. PFAS quality control samples were collected per matrix at the following frequency: 1 field duplicate per twenty primary samples; 1 MS/MSD pair per twenty primary + field duplicate samples; 1 rinsate blank per day per type of decontamination event where non-dedicated equipment is used. 1 trip blank per day when aqueous PFAS samples are collected.

ATTACHMENT F (NEW)

EUROFINS PFAS STANDARD OPERATING PROCEDURE (REDACTED)

eurofins	Always check on-line for validity.	Level:
Document number: **T-PFAS-WI14355**	**Polyfluorinated Alkyl Substances (PFASs) in Aqueous Samples by Method 537 Revision 1.1 Modified Using LC/MS/MS**	**Work Instruction**
Old Reference: **1-P-QM-WI-9039651 (1-P-QM-WI-9012802)**	REDACTED FOR PROPRIETARY CONTENT	
Version: **6**	Document users:	Organisation level: **5-Sub-BU**
Approved by: **UKA4** Effective Date **01-MAR-2018**	**6_EUUSLA_PFAS_Analyst, 6_EUUSLA_PFAS_Data_Reviewers, 6_EUUSLA_PFAS_Sample_Prep**	Responsible: **5_EUUSLA_PFAS_Manager**

LIMS ID

14091, 14343, 14344, 14434, 14465, 14473

Revision Log

PROPRIETARY CONTENT

Reference

1. US EPA Method 537 — Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LCMSMS), Version 1.1, Modified, September 2009.

2. Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LCMSMS), EPA 537 Version 1.1, Modified, September 2009. Department of Defense Quality System Manual Version 5.1, Table B-15.

3. Standard Test Method for Determination of Perfluorinated Compounds in Soil by Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS), ASTM Method D7968, 2014.

4. ISO 25101:2009(E) Water quality — Determination of perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) — Method for unfiltered samples using solid phase extraction and liquid chromatography/mass spectrometry. March 2009.

5. Method for Trace Level Analysis of C8, C9, C10, C11, and C13 Perfluorocarbon Carboxylic Acids in Water. Karen Risha, John Flaherty, Roice Wille, Warren Buck, Francesco Morandi, and Tsuguhide Isemura. Anal. Chem. 2005, 77, 1503-1508.

6. *Chemical Hygiene Plan*, current version.

Cross Reference

Document	Document Title
T-PEST-WI9847	Common Equations Used During Chromatographic Analyses
T-PFAS-WI13881	Standards Management in the PFAS Laboratory

Scope

This method is applicable for the determination of selected per- and polyfluorinated alkyl substances (PFAS) in aqueous samples to include non-potable waters and non-regulatory potable water when directed by the client. The compounds analyzed in this method are listed in the table below. The most current MDLs and LOQs are listed in the LIMS.

Analyte	Acronym	CAS#
Perfluorobutanesulfonic acid	PFBS	375-73-5
Perfluorodecanoic acid	PFDA	335-76-2
Perfluorododecanoic acid	PFDoDA	307-55-1
Perfluoroheptanoic acid	PFHpA	375-85-9
Perfluorohexanesulfonic acid	PFHxS	355-46-4
Perfluorohexanoic acid	PFHxA	307-24-4
Perfluorononanoic acid	PFNA	375-95-1
Perfluorooctanesulfonic acid	PFOS	1763-23-1
Perfluorooctanoic acid	PFOA	335-67-1
Perfluorotetradecanoic acid	PFTeDA	376-06-7
Perfluorotridecanoic acid	PFTrDA	72629-94-8
Perfluoroundecanoic acid	PFUnDA	2058-94-8
Perfluoro-n-butanoic acid	PFBA	375-22-4
Perfluoro-n-pentanoic acid	PFPeA	2706-90-3
8:2 - Fluorotelomersulfonate	8:2FTS	39108-34-4
N-methylperfluoro-1-octanesulfonamidoacetic acid	NMeFOSAA	2355-31-9
N-ethylperfluoro-1-octanesulfonamidoacetic acid Perfluoroundecanoic acid	NEtFOSAA	2991-50-6
4:2-Fluorotelomersulfonate	4:2-FTS	757124-72-4
Perfluoropentanesulfonate	PFPeS	2706-94-4
6:2-Fluorotelomersulfonate	6:2-FTS	27619-97-2

Perfluoroheptanesulfonate	PFHpS	375-92-8
Perfluorononanesulfonate	PFNS	474511-07-4
Perfluorodecanesulfonate	PFDS	335-77-3
10:2-Fluorotelomersulfonate	10:2-FTS	120226-60-0
Perfluorododecanesulfonate	PFDoDS	79780-39-5
Perfluorohexadecanoic acid	PFHxDA	67905-19-5
Perfluorooctadecanoic acid	PFODA	16517-17-6
Perfluorooctanesulfonamide	PFOSA	754-91-6
2-(N-methylperfluoro-1-octanesulfonamido)-ethanol	NMePFOSAE	24448-09-7
N-methylperfluoro-1-octanesulfonamide	NMePFOSA	31506-32-8
2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol	NEtPFOSAE	1691-99-2
N-ethylperfluoro-1-octanesulfonamide	NEtPFOSA	4151-50-2

Basic Principles

A 250-mL aqueous sample is fortified with isotopically-labeled extraction standards and is passed through a solid phase extraction (SPE) cartridge to extract the analytes. The compounds are eluted from the solid phase with a combination of solvents. The extract is concentrated to ~400-500ul with nitrogen in a heated water bath, and then reconstituted to 1ml with methanol. Isotopically-labeled injection internal standards are added to the sample extract and it is analyzed by LC/MS/MS operated in negative electrospray ionization (ESI) mode for detection and quantification of the analytes. Quantitative analysis is performed using isotope dilution.

Reference Modifications

EPA Method 537 is written specifically for the analysis of drinking water samples. The following modifications to the method have been made to accommodate all aqueous samples.

1. A labeled isotopic analog is spiked into samples for all compounds where an isotopic analog is commercially available. These isotopic compounds are referred to as extraction standards. For those compounds, an isotope dilution calibration model is used. Where labeled isotopes are not available, an internal standard calibration model using the extraction standards is used.

2. Prior to instrumental analysis, separate but similar isotopic analogs are added to the sample extract prior to instrumental analysis. Using an internal standard calibration model these injection standards are used to calculate recoveries of the extraction standards..

3. Field reagent blanks are not processed as listed in EPA 537 Version 1.1 section 8.3

4. Trizma is not used for waters except in the cases where the water comes from a chlorinated water source.
5. Branched isomers of PFOS, PFHxS, NetFOSAA and NMeFOSAA are not included in the calibration curves.
6. Peak asymmetry factors are not calculated.
7. MRL confirmation is not performed.
8. Spike concentrations are not rotated between low, medium and high levels.
9. SPE is used for sample preparation. Cartridge types and elution profiles differ from EPA 537 Version 1.1

MDL studies and IDOCs have been performed to validate method performance.

Interferences

Compounds which have similar structures to the compounds of interest and similar molecular weights would potentially interfere. Method interferences may be caused by contaminants in solvents, reagents (including reagent water), sample bottles and caps, and other sample processing hardware that lead to discrete artifacts and/or elevated baselines in the chromatograms. The analytes in this method can also be found in many common laboratory supplies and equipment, such as PTFE (polytetrafluoroethylene) products, LC solvent lines, methanol, aluminum foil, etc. A laboratory blank is performed with each batch of samples to demonstrate that the extraction system is free of contaminants.

Precaution to Minimize Method Interference

PROPRIETARY CONTENT

Safety Precautions and Waste Handling

See *Chemical Hygiene Plan* for general information regarding employee safety, waste management, and pollution prevention.

The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined. PFOA has been described as “likely to be carcinogenic to humans”. Each chemical should be treated as a potential health hazard and exposure to these chemicals should be minimized.

Exposure to these chemicals must be reduced to the lowest possible level by whatever means available, such as fume hoods, lab coats, safety glasses, and gloves. Gloves, lab coats, and safety glasses should be worn when preparing standards and handling samples. Avoid inhaling solvents and chemicals and getting them on the skin. Wear gloves when handling neat materials. When working with acids and bases, take care not to come in contact and to wipe any spills. Always add acid to water when preparing reagents containing concentrated acids.

All laboratory waste is accumulated, managed, and disposed of in accordance with all Federal, State, and local laws and regulations. All solvent waste and extracts are collected in approved solvent waste containers in the laboratory and subsequently emptied by personnel trained in hazardous waste disposal into the lab-wide disposal facility. HPLC vials are disposed of in the lab container for waste vials, and subsequently lab packed. Any solid waste material (disposable pipettes and broken glassware, etc.) may be disposed of in the normal solid waste collection containers.

Personnel Training and Qualifications

All personnel performing this procedure must have documentation of reading, understanding, and agreeing to follow the current version of this SOP and an annual documented Demonstration of Capability (DOC).

Initially, each chemist performing the extraction must work with an experienced employee for a period of time until they can independently perform the extraction. Also, several batches of sample extractions must be performed under the direct observation of another experienced chemist to assure the trainee is capable of independent preparation. During the training period, the new chemist may also learn the operation of the LC/MS/MS, calibration techniques, data processing and review, and maintenance procedures. Proficiency is measured through a documented Initial Demonstration of Capability (IDOC)

The IDOC and DOC consist of four laboratory control samples (or alternatively, one blind sample for the DOC) that is carried through all steps of the extraction and meets the defined acceptance criteria. The criteria include the calculation of mean accuracy and standard deviation.

Sample Collection, Preservation, and Handling

A. Sample Collection

The samples are collected in 250 mL polyethylene bottles containing 1.25 grams of Trizma, resulting in a Trizma concentration in the sample of 5 g/L. Trizma functions as a free chlorine scavenger; therefore, any chlorinated water supplies require the preservative. Water samples from non-chlorinated water sources would not necessarily require the Trizma preservative. Keep the sample sealed from time of collection until extraction.

NOTE: PFAS contamination during sampling can occur from a number of common sources, such as food packaging and certain foods and beverages. Proper hand washing and wearing nitrile gloves will aid in minimizing this type of accidental contamination of the samples.

B. Sample Storage and Shipment

1. Samples must be chilled during shipment and must not exceed 10°C during the first 48 hours after collection. Sample temperature must be confirmed to be at or below 10°C when the samples are received at the laboratory.

2. Samples stored in the lab must be held at a temperature of 0° to 6°C, not frozen, until extraction.

3. Water samples must be extracted within 14 days. Extracts must be analyzed

within 28 days after extraction. Extracts are stored at room temperature.

Apparatus and Equipment

PROPRIETARY CONTENT – LC/MS/MS that functions in ESI negative ION mode.

Reagents and Standards

All solvents, acids, and bases are stored in glass bottles in flammable proof cabinets or pressure resistant steel drums. Solvents, acids, and bases are stored at ambient temperature for up to 1 year. All non-solvents are stored according to manufacturer's storage conditions.

A. Reagents:

PROPRIETARY CONTENT

B. Standards: See SOP T-PFAS-WI13881

Calibration

A. Initial Calibration

1. A minimum of five calibration standards are required. In general, Cal1, Cal2, Cal3, Cal4, Cal5, Cal6, and Cal 7 are included in the initial calibration. S/N ratio must be ≥ 10:1 for all ions used for quantification.

2. Initially an MDL standard is analyzed to ensure all compounds can be detected at the MDL level. Following the MDL standard, the Cal1-Cal7calibration standards are analyzed. If compounds are not detected in the MDL standard, the source of the problem must be determined and the MDL standard reanalyzed.

3. Analyze a Cal3 level standard that contains linear and branch chained isomers of PFOA, PFOS and PFHxS. The analysis of this standard is used to demonstrate where the branch chained isomers elute and not included in the calibration curve. This will assist the chemist in identifying and properly integrating these compounds in samples.

4. Fit the curve with a linear through zero or linear with a concentration weighing factor of 1/x or quadratic regression with a concentration weighing factor $1/x^2$.

5. Isotopically labeled compounds are not available for PFPeS, PFHpS, PFNS, PFDS, PFDoS, 10:2-FTS, PFTrA, PFHxDA, and PFODA. See below for referenced extraction standards.

Compound	Extraction standard
PFPeS	13C3-PFBS
PFHpS	13C3-PFHxS
PFNS	13C8-PFOS
PFDS	13C8-PFOS
PFDoS	13C8-PFOS
10:2-FTS	13C2-8:2-FTS
PFTrDA	13C2-PFDoDA
PFHxDA	13C2-PFTeDA
PFODA	13C2-PFTeDA

6. Initial calibration acceptance criteria

When each calibration point, except the lowest point (Cal1), is calculated back against the curve, the back calculated concentration should be within ±70-130% of its true value. The lowest calibration point (Cal1) should calculate to be within ±50-150% of its true value. The R^2 value for each calibration curve must be ≥ 0.99 for each analyte.

DoD QSM5.1 criteria:

a. All calibration points must be within ±70-130% of their true values.

b. The %RSD of the response factors for all analytes must be < 20%.

If the criteria are not met, the source of the problem must be determined and corrected. Situations may exist where the initial calibration can be used. In those cases, the data will be reported with a qualifying comment.

7. Initial Calibration Verification (ICV)

A check standard prepared from a second source (ICV) is injected to confirm the validity of the calibration curve/standard. The calculated amount for each analyte should be ± 30% of the true value.

B. Continuing calibration

1. Once the calibration curve has been established, the continuing accuracy must be verified by analysis of a continuing calibration verification (CCV) standard every ten samples and at the end of the analysis sequence.

a. The CCV run after the initial calibration must be at the CAL3 level.

b. Subsequent CCV standards should alternate between the low, mid and high levels of the calibration curve.

DoD QSM5.1 criteria: The CCV standards must alternate between the CAL1-CAL3 levels. All analyte concentrations must be within ±30% of their true values.

2. Acceptance criteria

a. The calculated amount for each compound (native and extraction standard) in the CCV standard must be within ±30% of the true value. Samples that are not bracketed by acceptable CCV analyses must be reanalyzed. The exception to this would be if the CCV recoveries are high, indicating increased sensitivity, and there are no positive detections in the associated samples, the data may be reported with a qualifying comment.

DoD QSM5.1 criteria: If acceptance criteria are not met, immediately analyze two additional consecutive CCVs. If both pass acceptance criteria, samples may be reported without reanalysis. If either fail, or two consecutive CCVs cannot be run, repeat CCV and reanalyze all samples since last successful CCV.

b. The absolute areas of the injection internal standards should be within 50-150% of the average areas measured during the initial calibration.

Procedure

A. Sample Preparation - **<u>all samples</u>**

1. Mark the outside of each sample container with pen ("Sharpie") to record the level of the sample in the container prior to extraction.

2. If required, add 1.25 grams of Trizma to a 250 ml HDPE bottle for the laboratory reagent blank (LRB) and the lab fortified blank (LFB). Fill each bottle with 250 ml of Milli-Q water. Record 250 ml as the volume for the batch QC samples on the batchlog.

3. If sample has dissolved and/or settleable solid content; i.e., is cloudy or has a layer of sediment/solids at the bottom of the bottle, an aliquot should be taken from the original bottle and diluted with reagent water in order to minimize difficulty passing through the SPE sorbent bed. If unsure whether or not less-than-full sample volume should be used for SPE extraction, consult a supervisor.

a. Determine aliquot to be used for extraction (50ml; 100ml).

b. Label a clean 250ml HDPE bottle with associated ELLE sample number.

c. Label appropriate number of 50ml centrifuge tubes.

d. Shake/invert sample bottle to thoroughly mix the sample before pouring aliquot(s).

e. Pour sample from original bottle into centrifuge tubes. Cap tubes and centrifuge for 5 minutes at full speed (one full cycle).

f. On a calibrated, top-loading balance, place labeled empty 250ml PP wide-mouthed bottle.

g. Decant centrifuged sample aliquot(s) from centrifuge tube(s) to the 250ml bottle until desired volume (weight in grams) is reached. 100g = 100ml; 50g = 50ml, etc.

h. Add Milli-Q water to the bottle until a weight of 250g (total of 250ml) is reached.

i. Shake/invert several times to mix thoroughly.

j. Record the aliquot taken from the original bottle (50ml; 100ml) as the sample volume.

B. Solid Phase Extraction (SPE) - **<u>all samples</u>**

PROPRIETARY CONTENT

15. Reconstitute to 1.0 ml with 100% methanol. Vortex to mix. Centrifuge all 15 ml collection tubes at for 5 minute at full speed (~4100 rpm).

16. Place each empty sample bottle on the top-loading balance and tare.

17. Fill each tared sample container to the mark placed on the bottle prior to extraction with DI water.

18. Record the weight as the sample volume on the batchlog.

19. Transfer 400 µL of the final extract to labeled auto-sampler vials. Add 20 ul of labeled internal standard spike and cap and vortex the auto-sampler vial. Samples are now ready for analysis.

20. Cap the centrifuge tube. Store the remaining centrifuged extracts at room temperature for dilution or reinjection if needed.

C. **<u>Extract Treatment for DoD samples:</u>**

PROPRIETARY CONTENT

D. <u>Serial Dilution Sample Prep</u>

PROPRIETARY CONTENT

E. LC/MS/MS Analysis

1. Mass Calibration and Tuning

a. At instrument set up and installation and after the performance of major maintenance, calibrate the mass scale of the MS with calibration compounds and procedures described by the manufacturer. The entire mass range must be calibrated.

b. When masses fall outside of the ±0.5 amu of the true value, the instrument must be retuned using PPG according to the manufacturer's specifications. Mass assignments of the tuning standard must be within 0.5 amu of the true value. Refer to the instrument manufacturer's instructions for tuning and conditions. These values are stored in the tune file for future reference.

2. The mass spectral acquisition rate must include a minimum of 10 spectra scans across each chromatographic peak.

3. Acquisition method: See attachment 1

4. DoD QSM5.1 criteria for Instrument Sensitivity Check (ISC) and Instrument Blanks

a. Prior to sample analysis and at least every 12 hours, an instrument sensitivity check (ISC) must be performed. The CAL1 standard will be analyzed. All analyte concentrations must be within +/-30 of their true values. If the criteria is not met, correct problem and rerun ISC. If problem persists, repeat the ICAL. No samples can be analyzed until the ISC meets acceptance criteria.

b. Instrument blanks need to be analyzed immediately following the highest standard analyzed and daily or at the start of a sequence. The concentration of all analytes must be ≤ 1/2 the LOQ. If acceptance criteria are not met the calibration must be performed using a lower concentration standard for the high standard until the criteria are met.

5. Load sample vials containing standards, quality control samples, and sample extracts into autosampler tray. Allow the instrument adequate time to equilibrate to ensure the mass spec and LC have reached operating conditions (approximately 5 minutes) before the first injection. Analyze several solvent blanks clean the instrument prior to sample acquisition.

6. After the initial calibration, inject a solvent blank, followed by the ICV, L/B standard, closing Cal 3 level CCV , CCV, extraction batch QC, and samples. Bracket each set of ten samples with a CCV standard, alternating between the Cal3, Cal4, and Cal5 levels.

Note: For DoD QSM5.1: CCVs will range from the CAL1 to the CAL3 level standard.

7. After injections are completed, check all CCV recoveries and absolute areas to make sure they are within method control limits. See Calibration section B.2 for acceptance criteria. Process each chromatogram and closely evaluate all integrations, baseline anomalies, and retention time differences.

If manual integrations are performed, they must be documented and a reason given for the change in integrations. The manual integrations are documented during data processing and all original integrations are reported at the end of the sample PDF file with the reason for manual integration clearly listed.

8. Quantitate results for the extraction blank.

a. Non-DoD criteria: No target analytes at or above the reporting limit may be found in the extraction blank for acceptable batch results. If a target analyte is detected in the extraction blank but not detected in the sample, the data is reported. If a target analyte is detected in the method blank at a concentration greater than the reporting limit and also in the sample, the sample must be reextracted. If the target analyte in the sample is detected at a concentration greater than 10 times the amount detected in the method blank, the data is reported.

b. DoD QSM5.1 criteria: No target analytes detected > 1/2 the LOQ or > 1/10 the regulatory limit, whichever is greater. If criteria is exceeded, reextract all samples with positive detections associated with the method blank.

9. Calculate the recoveries of spiked analytes for the LCS, matrix spike and matrix spike duplicate (MS/MSD) by comparing concentrations observed to the true values. The advisory QC acceptance limits for LCS and MS/MSD recovery are 70 to 130% for each analyte. The advisory QC acceptance limit for the relative percent difference (%RPD) between LCS/LCSD and MS/MSD is ≤30%. If LCS and/or LCSD recoveries are acceptable, proceed to sample quantitation. If the LCS recoveries are unacceptable, the samples associated with the LCS may need to be reanalyzed. If LCS recoveries are above the advisory QC acceptance limits, and there are no positive detections in the sample, the data may be reported. If MS/MSD recoveries are outside QC acceptance criteria, the associated data will be flagged or noted in the comments section of the report.

10. Isotopically labeled extraction standards are added to all samples, extraction blank, LCS/LCSD, and MS/MSD prior to extraction.

a. Non-DoD criteria: The recovery of the extraction standards should be within QC acceptance criteria. If the extraction standard recovery(ies) is(are) outside the QC limit(s), consult a supervisor to determine the appropriate course of action based on batch and sample results.

b. DoD QSM5.1 criteria: All extraction standard recoveries must be within 50% to 150% of the true value. If recoveries are outside the acceptance criteria, samples must be reextracted.

11. Isotopically labeled injection standards are added to each QC and field sample extract prior to analysis.

a. Non-DoD criteria: The absolute areas of the injection standards should be within 50-150% of the average areas measured during the initial calibration. If the internal standards are recovered outside 50-150%, consult a supervisor to determine the appropriate course of action based on batch and sample results.

b. DoD QSM5.1 criteria: Peak areas must be within -50% to +50% of the area measured in the ICAL midpoint standard. On days when an ICAL is not performed, the peak areas must be within -50% to +50% of the peak area measured in the daily initial CCV. If injection internal standards fall outside the acceptance window, analyze a second aliquot of the extract. If none remains, reanalyze the first aliquot.

12. Compare the retention times of all of the analytes, surrogates and internals standards. The relative retention times should not vary by more than 0.2 retention time units.

13. The MDL standard and the linear/branch chain standard are used when assessing the correctness of the computer generated peak integrations. For results that have responses at or near the MDL, the analysts will calculate 1/2 of the area ratio of that compound in the MDL standard. If the area ratio for the compound in the sample exceeds that 1/2 the area ratio from the MDL standard, the peak is reported as a positive detection.

14. If the calculated concentation exceeds the calibration range of the system, dilute the extract with MeOH and add the appropriate amount of extraction standard to match the original concentration. Add 10 ul of injection internal standard and analyze the dilution.

Dilution Example 1/10: Mix 0.877 mL of MEOH with 0.100 mL of sample extract and 0.0225 mL of labeled extraction standard. Vortex to mix. Using an auto-pipette, transfer 200 uL of the mixed solution into a labeled auto-sampler vial containing a plastic insert. Using a syringe, add 10 uL of labeled injection std to the 200 uL aliquot. Cap and vortex thoroughly to mix.

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Calculations

A. Peak Area Ratio

$$Peak\ Area\ Ratio = \frac{Analyte\ Response}{Labeled\ Analyte\ Response}$$

B. Analyte Concentration using linear through zero curves (MQ Data processing system)

Concentration = (area ratio ÷ slope) x Dilution Factor x Internal Standard concentration

Where: internal standard concentration = 1 ng/ml

C. Sample Concentration (used only for aqueous samples using the MultiQuant data processing system on the AB Sciex LC/MS/MS)

Sample concentration (ng/l) = Calc conc x (Sample volume ÷ Sample weight) x DF

D. See *T-PEST-WI9847* for additional calculations used to evaluate the calibrations and quality control samples.

Statistical Information/Method Performance

The method is evaluated through both initial and ongoing Demonstrations of Capability (IDOC and DOC). The IDOC includes performance of quad studies, MDL studies, and when available, acceptable scores obtained in Performance Testing (PT) studies. Annual MDL studies are performed as are annual analyst DOCs.

Quality Assurance/Quality Control

For each batch of samples extracted, a method blank, an LCS/LCSD (Milli Q water spiked with all compounds to be determined carried through the entire procedure), and an MS must be extracted. If an MSD is submitted then an LCSD would not be extracted. A batch is defined as the samples to be extracted on any given day, but not to exceed 20 field samples. If more than 20 samples are prepared in a day, an additional batch must be prepared. If any client, state, or agency has more stringent QC or batching requirements, these must be followed instead. Statistical control limits must be calculated for recoveries of LCS and MS when sufficient data points have been collected

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T-PEST-WI9847 Common Equations Used During Chromatographic Analyses T-PFAS-WI13881 Standards Management in the PFAS Laboratory

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Attachment:
Attachment 1
Attachment 2

End of document

Version history

Version	Approval	Revision information
4	03.JAN.2018	
5	24.FEB.2018	
6	01.MAR.2018	

ATTACHMENTS REFERENCED HEREIN,
BUT NOT INCLUDED IN REVISED WORK PLAN OR SAP

TECHNICAL MEMORANDUM
REVIEW OF TENTATIVELY IDENTIFIED COMPOUNDS IN GROUNDWATER,
DELAWARE SAND & GRAVEL SUPERFUND SITE, NEW CASTLE, DELAWARE
BY GOLDER ASSOCIATES INC., DATED DECEMBER 21, 2016

Golder Associates

TECHNICAL MEMORANDUM

Date: December 21, 2016 **Project No:** 013-6052-011

To: DS&G Remedial Steering Committee

From: Theresa Miller, PG, LSP and Ross Bennett, PE

cc: Doug Sutton, PhD, PE, LEED AP (HGL)

RE: **REVIEW OF TENTATIVELY IDENTIFIED COMPOUNDS IN GROUNDWATER DELAWARE SAND & GRAVEL SUPERFUND SITE, NEW CASTLE, DELAWARE**

1.0 INTRODUCTION

As requested by the United States Environmental Protection Agency (USEPA) via email dated October 28, 2016, Golder Associates Inc. (Golder) updated our review of the Tentatively Identified Compounds (TICs) for the Delaware Sand & Gravel Superfund Site (the Site). The USEPA requested the Trust review TICs identified in Site groundwater samples in response to a comment from the Proposed Plan public meeting regarding "potential groundwater contaminants that may not be on the target analyte list [TAL] for the Site". As indicated in the USEPA's email, "In 2012 …, Golder compared compounds on the EPA's Target Compound List (TCL) for VOCs and SVOCs (SOM01.2) and compounds for which DNREC has issued Uniform Risk-Based Remediation Standards (URSs)[1] with Site groundwater TICs and, as a result of this analysis, directed their lab to add 9 of the TICs to the [TAL]." As part of the current review, the USEPA specifically requested "a summary and assessment (for possible inclusion on the lab's [TAL]) of all of the groundwater TICs"[2]. Golder notes that in addition to the nine compounds added to the TAL for the Site in 2012, bisphenol A was added to the Site's TAL in 2014 based on a review of TICs from the 2013 monitoring events.

The following provides: 1) a summary of TICs for the 2015 and 2016 groundwater monitoring events, 2) comparison of the TICs to the USEPA's Superfund Organic Methods (SOM) analyte list, 3) comparison of estimated TIC concentrations to applicable standards and screening values, and 4) recommendations for compounds to be added to the TAL for the Site.

2.0 REVIEW OF TICS

2.1 Summary

In response to the USEPA's request, Table A (see attached) summarizes the TIC data from four consecutive routine groundwater monitoring events: Spring 2015, Fall 2015, Spring 2016, and Fall 2016. Table A also provides the number of TIC detections overall and per monitoring event, as well as summarizing the number of TIC detections based on general location as described below.

To identify TICs for possible inclusion on the Site's TAL, Golder reviewed the frequency of TIC detections and general area of TIC detections (e.g., Columbia Aquifer, UPCUTZ, UPA both upgradient and downgradient of well PW-1(U)). To provide consistency with the USEPA's previous review and comments on our 2013 TIC review, Golder used the USEPA's recommended threshold of greater than or

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[1] Footnote added to quoted text for clarification. Since January 1, 2013, DNREC uses Screening Level Values (SLVs) in lieu of the URSs.

[2] The full text of the USEPA's request was "a summary and assessment (for possible inclusion on the lab's target analyte list) of all of the groundwater TICs, not only those covered by EPA's TCL and DNREC's URSs." This request implies that past evaluations were limited to compounds on the USEPA's TCL and DNREC's URSs. However, the TIC evaluations completed in 2012 and 2013 included all TICs and the comparison was not limited to the USEPA's TCL and DNREC's URSs.

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equal to 6 TIC detections per monitoring event[3] to determine if a TIC should be evaluated further. This resulted in a list of 11 "frequently detected" TICs as presented in Table B. Table B presents a detailed summary of "frequently detected" TICs with greater than 6 detections in at least two events for the 2015-2016 period. The other "low frequency" TICs were generally detected in 10 or fewer total samples collected during the four monitoring events[4].

2.2 Comparison of Estimated TIC Concentrations to Standards

Golder compared the list of TICs to the lists of compounds for which there are USEPA maximum contaminant levels (MCLs), USEPA health advisory levels (HALs)[5], USEPA regional screening levels (RSLs; dated May 2016), or DNREC SLVs[6] or HALs. Golder did not identify any TICs for which there are USEPA MCLs, USEPA HALs or DNREC HALs. Due to the continued review of TICs and updating of the TAL at this Site, the list of TICs currently under review (see Table A) generally does not include compounds for which there are RSLs or SLVs.

It should be noted that the estimated TIC "concentrations" on Table B are estimates and cannot be compared to numerical standards because the actual calibrated concentrations for these compounds have the potential to be orders of magnitude higher or lower than the estimated TIC concentrations.

2.3 Comparison of Analyte Lists

Golder compared the USEPA's current TCL for VOCs and SVOCs (SOM02.3; which supercedes SOM01.2 used in Golder's 2012 TIC analysis) to the reported TAL compounds and the TICs for the Site. Based on this comparison, there are 13 compounds which are not currently being analyzed for as TAL compounds and have not been estimated as TICs between the Spring 2015 and Fall 2016 monitoring events. These compounds include:

Compound	CAS No.	Notes
Dichlorodifluoromethane	75-71-8	
Trichlorofluoromethane	75-69-4	
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	
Methyl acetate	79-20-9	
Bromochloromethane	74-97-5	
1,2-Dibromoethane	106-93-4	
1,2-Dibromo-3-chloropropane	96-12-8	
1,2,3-Trichlorobenzene	87-61-6	
Benzaldehyde	100-52-7	
Acetophenone	98-86-2	
1,2,4,5-Tetrachlorobenzene	95-94-3	
2,3,4,6-Tetrachlorophenol	58-90-2	
m,p-Xylene	179601-23-1	Included on TAL as total xylenes

[3] As stated in the July 18, 2013 email from Linda Watson (USEPA toxicologist) to Debra Rossi (USEPA remedial project manager), "I would agree any TIC detected more than 6 times is definitely worth pursuing."

[4] Exceptions to this statement are Octahydro-1H-azonine and Desmetryn which were only detected in samples from the April 2015 monitoring event.

[5] Drinking Water Standards and Health Advisories, 2012 Edition, USEPA Office of Drinking Water EPA 822-S-12-001.

[6] DNREC Screening Level Table dated January 1, 2013 updated July 2016.

Based on a comparison of the lists as described above, there are 3 compounds which have not been analyzed for as target compounds, but have been estimated as TICs between the Spring 2015 and Fall 2016 monitoring events. These compounds are:

Compound	CAS No.	Notes
o-Xylene	95-47-6	Included on TAL as total xylenes
3-Methylphenol	108-39-4	Detected one time
1,1'Biphenyl	92-52-4	Detected one time

None of the "frequently detected" TICs on Table B are included on the USEPA's TCL for VOCs or SVOCs (currently SOM02.3).

3.0 FINDINGS

Based on the review of data and TCL comparisons described above, there are 11 "frequently detected" TICs as shown on Table B that Golder considered for addition to the TAL currently used by TestAmerica for analysis of samples collected from the Site. TestAmerica indicated that two of these compounds (indane and fluorodichloromethane) are currently on-line and can be added to the Site's TAL for the next monitoring event. Because N-methyl aniline and 1,2,3-trimethylbenzene have USEPA RSLs and/or DNREC SLVs, Golder and TestAmerica have discussed the logistics and cost to bring these two compounds on-line at its Edison facility.

CAS RN	Chemical Name	Currently On-Line at Test America-Edison	DNREC GW-SLV and/or USEPA RSL (ug/L)	Average (rounded) Detections per Event
496-11-7	Indane	Yes	NA	28
526-73-8	Benzene, 1,2,3-trimethyl-	No*	1	27
611-14-3	Benzene, 1-ethyl-2-methyl-	No	NA	19
620-14-4	Benzene, 1-ethyl-3-methyl-	No	NA	17
100-61-8	Aniline, N-methyl-	No*	3.8	8
1205-91-0	1,4-Benzenediol, diacetate	No	NA	8
4812-20-8	2-Isopropoxyphenol	No	NA	7
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-	No	NA	6
1025-15-6	Triallyl isocyanurate	No	NA	5
75-43-4	Fluorodichloromethane	Yes	NA	5
827-16-7	1,3,5-Trimethylcyanuric Acid	No	NA	4

* indicates Golder and TestAmerica have discussed bringing this compound online at its Edison facility.
NA = not available

4.0 RECOMMENDATIONS

Based on the information presented above, Golder recommends adding four of the “frequently detected” TICs to the Site’s TAL due to the existence of a USEPA RSL and/or DNREC SLV, and/or because they are on-line with TestAmerica-Edison. It is anticipated that these compounds will be added to the Site’s TAL for the April 2017 semi-annual monitoring event.

CAS RN	Chemical Name	Currently On-Line at Test America-Edison	DNREC GW-SLV and/or USEPA RSL (ug/L)	Average (rounded) Number of TIC Detects per Event
496-11-7	Indane	Yes	NA	28
526-73-8	Benzene, 1,2,3-trimethyl-	No*	1	27
100-61-8	Aniline, N-methyl-	No*	3.8	8
75-43-4	Fluorodichloromethane	Yes	NA	5

* indicates Golder and TestAmerica have discussed bringing this compound online at its Edison facility.
NA = not available

Enclosures

Table A Summary of 2015-2016 Tentatively Identified Compound Data
Table B Summary of 2015-2016 Frequently Detected Tentatively Identified Compound Data by Well

Table A
Summary of 2015-2016 Tentatively Identified Compound Data
Delaware Sand & Gravel Superfund Site
New Castle, Delaware

				Count of TIC Detections Per Event				Number of Wells with at Least 1 TIC Detection				
CAS Number	**Compound**	**DNREC GW-SLV and/or USEPA RSL (ug/L)**	**Total Number of TIC Detections 2015-2016**	**Spring 2015**	**Fall 2015**	**Spring 2016**	**Fall 2016**	**DDA Vicinity - Columbia**	**Well PW-1(U) Vicinity - UPA and UPCUTZ**	**Well P-6/UPA-101 Vicinity - UPA and UPCUTZ**	**Down-gradient of Well PW-1(U) - UPA**	**NCC Monitor-ing Wells**
496-11-7	Indane	NA	111	37	22	30	22	15	11	3	1	0
526-73-8	Benzene, 1,2,3-trimethyl-	1	108	35	23	30	20	12	8	3	0	0
611-14-3	Benzene, 1-ethyl-2-methyl-	NA	75	27	15	22	11	11	7	3	0	0
620-14-4	Benzene, 1-ethyl-3-methyl-	NA	67	20	13	16	18	10	8	2	0	0
100-61-8	Aniline, N-methyl-	3.8	32	6	7	11	8	4	4	3	2	1
1205-91-0	1,4-Benzenediol, diacetate	NA	31	19	3	6	3	4	6	3	1	0
4812-20-8	2-Isopropoxyphenol	NA	29	9	7	10	3	2	5	3	1	0
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-	NA	24	5	6	9	4	3	7	2	1	0
1025-15-6	Triallyl isocyanurate	NA	21	3	4	8	6	6	6	0	0	0
75-43-4	Fluorodichloromethane	NA	21	4	6	6	5	1	3	3	1	0
827-16-7	1,3,5-Trimethylcyanuric Acid	NA	17	9	6	1	1	3	4	2	2	1
621-87-4	2-Propanone, 1-phenoxy-	NA	14	3	4	4	3	0	1	2	1	0
622-96-8	Benzene, 1-ethyl-4-methyl-	NA	14	4	2	4	4	5	3	2	0	0
5661-71-2	1H-Azonine, octahydro-	NA	13	13	0	0	0	5	4	1	1	1
770-35-4	1-Phenoxypropan-2-ol	NA	13	4	3	3	3	1	3	2	0	0
1014-69-3	Desmetryn	NA	11	11	0	0	0	8	1	1	1	0
108-38-3	Benzene, 1,3-dimethyl-	19	11	3	3	3	2	4	0	1	0	0
1758-88-9	Benzene, 2-ethyl-1,4-dimethyl-	NA	11	4	3	3	1	5	1	0	0	0
527-84-4	Benzene, 1-methyl-2-(1-methylethyl)-	NA	10	4	3	3	0	4	2	0	0	0
6180-61-6	1-Propanol, 3-phenoxy-	NA	10	2	2	3	3	0	2	3	0	0
6280-98-4	Benzene, 1,2-dipropoxy-	NA	10	1	7	1	1	3	3	2	2	0
67-63-0	Isopropyl alcohol	41	10	1	1	7	1	2	3	0	0	4
108-83-8	4-Heptanone, 2,6-dimethyl-	NA	9	4	2	1	2	3	0	0	0	0
111-06-8	Hexadecanoic acid, butyl ester	NA	8	1	0	4	3	2	2	0	4	0
19549-80-5	2-Heptanone, 4,6-dimethyl-	NA	8	3	3	1	1	3	1	0	0	0
488-23-3	Benzene, 1,2,3,4-tetramethyl-	NA	8	3	3	2	0	2	2	0	0	0
579-10-2	Acetamide, N-methyl-N-phenyl-	NA	8	4	0	4	0	2	3	0	2	0
933-98-2	Benzene, 1-ethyl-2,3-dimethyl-	NA	8	3	2	1	2	3	2	0	0	0
934-80-5	Benzene, 4-ethyl-1,2-dimethyl-	NA	8	3	1	2	2	3	3	0	0	0
98-54-4	Phenol, p-tert-butyl-	NA	8	1	5	2	0	6	1	0	0	0
102-82-9	Tributylamine	NA	7	2	5	0	0	1	1	0	4	1
1675-54-3	Oxirane, 2,2'-[(1-methylethylidene)bis(4…	NA	7	1	1	1	4	5	0	0	0	0
565-59-3	2,3-Dimethylpentane	NA	7	0	0	3	4	2	4	0	0	0
632-22-4	Urea, tetramethyl-	NA	7	1	0	5	1	2	2	0	2	0
994-05-8	Butane, 2-methoxy-2-methyl-	NA	7	7	0	0	0	5	0	2	0	0
10544-50-0	Cyclic octaatomic sulfur	NA	6	0	0	6	0	2	4	0	0	0
95-93-2	Benzene, 1,2,4,5-tetramethyl-	NA	6	1	2	2	1	2	1	0	0	0
123-95-5	Octadecanoic acid, butyl ester	NA	5	0	0	2	3	1	0	0	3	0
140-66-9	Phenol, 4-(1,1,3,3-tetramethylbutyl)-	NA	5	2	1	1	1	2	2	1	0	0
822-50-4	trans-1,2-Dimethyl-cyclopentane	NA	5	0	0	4	1	1	4	0	0	0
872-56-0	Isopropylcyclobutane	NA	5	2	1	1	1	1	2	0	0	0
934-74-7	Benzene, 1-ethyl-3,5-dimethyl-	NA	5	1	1	2	1	2	2	0	0	0
106-42-3	p-Xylene	19	4	1	0	1	2	2	0	1	0	0
15980-15-1	1,4-Oxathiane	NA	4	1	1	1	1	1	0	0	0	0
31158-91-5	Hexadecanoic acid, 1,1-dimethylethyl est…	NA	4	0	0	1	3	1	1	0	2	0
471-46-5	Ethanediamide	NA	4	4	0	0	0	1	2	1	0	0
585-34-2	Phenol, m-tert-butyl-	NA	4	2	1	0	1	2	1	1	0	0
6135-31-5	Carbamic acid, ethyl-, methyl ester	NA	4	3	0	0	1	0	1	2	0	0
95-47-6	o-Xylene	19	4	1	0	0	3	1	0	3	0	0
108-58-7	1,3-Benzenediol, diacetate	NA	3	2	0	0	1	2	0	1	0	0
112-95-8	Eicosane	NA	3	0	0	0	3	1	1	0	0	1
115-07-1	Propene	630	3	2	0	1	0	0	2	1	0	0
2039-89-6	Benzene, 2-ethenyl-1,4-dimethyl-	NA	3	2	0	1	0	2	0	0	0	0
38256-93-8	2-Methoxy-N-methylethylamine	NA	3	3	0	0	0	0	1	1	1	0
40625-96-5	5-Methyl-2,4-diisopropylphenol	NA	3	1	1	0	1	2	0	0	0	0
589-34-4	Hexane, 3-methyl-	NA	3	2	1	0	0	0	2	0	0	0
611-15-4	Benzene, 1-ethenyl-2-methyl-	NA	3	0	0	0	3	2	1	0	0	0
645-05-6	Altretamine	NA	3	0	2	1	0	1	0	0	0	0
85877-56-1	4-Pentenoic acid, 2-(2-oxopropyl)-	NA	3	3	0	0	0	0	0	0	2	0
874-41-9	Benzene, 1-ethyl-2,4-dimethyl-	NA	3	1	1	1	0	3	0	0	0	0
934-34-9	2(3H)-Benzothiazolone	NA	3	1	1	0	1	1	0	0	1	0
96-37-7	Cyclopentane, methyl-	NA	3	0	1	1	1	1	1	0	0	0
1000147-75-1	1-(7-Methyl-6H-imidazo[1,2-a]pyrrolo[3,2…	NA	2	2	0	0	0	1	1	0	0	0
103-83-3	Dimethylbenzylamine	NA	2	0	0	1	1	1	1	0	0	0
1077-56-1	Benzenesulfonamide, N-ethyl-2-methyl-	NA	2	1	0	1	0	1	0	0	1	0
108-44-1	Benzenamine, 3-methyl-	NA	2	2	0	0	0	1	1	0	0	0
108-93-0	Cyclohexanol	NA	2	0	1	1	0	1	0	0	0	0
1168-42-9	4H-1-Benzopyran-4-one, 5,6,7-trimethoxy-…	NA	2	2	0	0	0	2	0	0	0	0
1192-18-3	Cyclopentane, 1,2-dimethyl-, cis-	NA	2	0	1	0	1	0	2	0	0	0
121-44-8	Triethylamine	1.5	2	1	0	1	0	0	2	0	0	0

Table A
Summary of 2015-2016 Tentatively Identified Compound Data
Delaware Sand & Gravel Superfund Site
New Castle, Delaware

				Count of TIC Detections Per Event				Number of Wells with at Least 1 TIC Detection				
CAS Number	Compound	DNREC GW-SLV and/or USEPA RSL (ug/L)	Total Number of TIC Detections 2015-2016	Spring 2015	Fall 2015	Spring 2016	Fall 2016	DDA Vicinity - Columbia	Well PW-1(U) Vicinity - UPA and UPCUTZ	Well P-6/UPA-101 Vicinity - UPA and UPCUTZ	Down-gradient of Well PW-1(U) - UPA	NCC Monitor-ing Wells
134-62-3	Diethyltoluamide	NA	2	0	1	1	0	1	0	0	0	0
135-01-3	Benzene, 1,2-diethyl-	NA	2	2	0	0	0	2	0	0	0	0
13513-82-1	O-Methoxy-.alpha.-methylbenzyl alcohol	NA	2	1	1	0	0	1	0	0	0	0
1560-06-1	Benzene, 2-butenyl-	NA	2	0	0	0	2	1	1	0	0	0
20324-33-8	2-Propanol, 1-[2-(2-methoxy-1-methyletho…	NA	2	2	0	0	0	0	1	1	0	0
2199-69-1	1,2-Dichlorobenzene-D4	NA	2	0	0	0	2	0	0	2	0	0
22606-87-7	Azetidine, 2,2,3,3-tetramethyl-	NA	2	2	0	0	0	0	1	0	1	0
2532-58-3	Cyclopentane, 1,3-dimethyl-, cis-	NA	2	1	0	0	1	2	0	0	0	0
26535-36-4	2H,8H-Benzo[1,2-b:3,4-b']dipyran-6-propa…	NA	2	2	0	0	0	2	0	0	0	0
3333-13-9	Benzene, 1-methyl-4-(2-propenyl)-	NA	2	1	0	0	1	2	0	0	0	0
3454-07-7	Benzene, 1-ethenyl-4-ethyl-	NA	2	0	0	2	0	1	1	0	0	0
4319-49-7	N-Aminomorpholine	NA	2	2	0	0	0	1	1	0	0	0
51-79-6	Urethane	0.025	2	1	0	1	0	0	1	0	0	0
55956-25-7	2-Propanol, 1-[1-methyl-2-(2-propenyloxy…	NA	2	2	0	0	0	0	0	2	0	0
57-11-4	Octadecanoic acid	NA	2	0	0	0	2	2	0	0	0	0
587-03-1	3-Methylbenzyl alcohol	NA	2	0	0	0	2	2	0	0	0	0
593-70-4	Methane, chlorofluoro-	NA	2	1	0	1	0	0	0	2	0	0
628-34-2	1-Chloro-2-ethoxyethane	NA	2	0	1	0	1	1	0	0	0	0
635-67-6	1,2-Benzenediol, diacetate	NA	2	0	0	0	2	2	0	0	0	0
75-65-0	tert-Butyl Alcohol	NA	2	0	1	1	0	1	0	1	0	0
7665-72-7	(tert-Butoxymethyl)oxirane	NA	2	2	0	0	0	0	0	2	0	0
815-24-7	3-Pentanone, 2,2,4,4-tetramethyl-	NA	2	2	0	0	0	2	0	0	0	0
873-49-4	Benzene, cyclopropyl-	NA	2	1	0	0	1	1	1	0	0	0
873-94-9	Cyclohexanone, 3,3,5-trimethyl-	NA	2	0	1	0	1	1	1	0	0	0
934-10-1	3-Phenylbut-1-ene	NA	2	1	1	0	0	2	0	0	0	0
1000190-36-6	4-(3-Hydroxy-2,2,6-trimethyl-7-oxa-bicyc…	NA	1	1	0	0	0	0	0	0	1	0
1000190-70-0	4-t-Butyl-4,5-dimethyl-[1,3]dioxane	NA	1	1	0	0	0	0	1	0	0	0
1000191-13-7	Tetracyclo[3.3.1.0(2,8).0(4,6)]-non-2-en…	NA	1	1	0	0	0	1	0	0	0	0
1000193-81-4	11,13-Dihydroxy-tetradec-5-enoic acid, m…	NA	1	0	0	1	0	0	0	1	0	0
1000269-58-2	Thiazolo[4,5-d]pyrimidin-7(6H)-one, 5-am…	NA	1	1	0	0	0	0	1	0	0	0
1000282-69-4	Methoxyacetic acid, cyclohexyl ester	NA	1	1	0	0	0	1	0	0	0	0
1000293-30-7	2-Methoxybenzoic acid, cyclopentyl ester…	NA	1	1	0	0	0	1	0	0	0	0
100-46-9	Benzylamine	NA	1	1	0	0	0	1	0	0	0	0
100910-92-7	1-Ethoxypentan-3-ol	NA	1	1	0	0	0	0	1	0	0	0
103-89-9	Acetamide, N-(4-methylphenyl)-	NA	1	0	0	0	1	0	0	1	0	0
105-05-5	Benzene, 1,4-diethyl-	NA	1	0	0	0	1	1	0	0	0	0
106-49-0	p-Toluidine	2.5	1	0	0	0	1	0	0	0	1	0
1069-53-0	Hexane, 2,3,5-trimethyl-	NA	1	1	0	0	0	1	0	0	0	0
107289-32-7	1,3-Dioxan-4-one, 2-(1,1-dimethylethyl)-…	NA	1	1	0	0	0	0	0	0	1	0
1074-43-7	Benzene, 1-methyl-3-propyl-	NA	1	0	0	0	1	1	0	0	0	0
108-39-4	Phenol, 3-methyl-	93	1	1	0	0	0	1	0	0	0	0
110-01-0	Thiophene, tetrahydro-	NA	1	1	0	0	0	1	0	0	0	0
114-26-1	Phenol, 2-(1-methylethoxy)-, methylcarba…	7.8	1	0	0	0	1	0	1	0	0	0
117888-04-7	2,4-Diethyl-6-methyl-1,3,5-trioxane	NA	1	1	0	0	0	0	0	1	0	0
120-72-9	Indole	NA	1	1	0	0	0	0	0	0	1	0
1207-72-3	10H-Phenothiazine, 10-methyl-	NA	1	1	0	0	0	1	0	0	0	0
123-73-9	2-Butenal, (E)-	0.04	1	0	0	0	1	1	0	0	0	0
126-73-8	Tributyl Phosphate	5.2	1	0	0	1	0	0	0	0	0	1
135056-17-6	2H-1,3-Dithiolo[4,5-c]coumarine, 2-dicya…	NA	1	1	0	0	0	1	0	0	0	0
141-93-5	Benzene, 1,3-diethyl-	NA	1	1	0	0	0	0	1	0	0	0
149-57-5	2-Ethylhexanoic Acid	NA	1	0	1	0	0	1	0	0	0	0
155726-87-7	2,2,4-Trimethyl-4-(4'-trimethylsilyloxyp…	NA	1	1	0	0	0	1	0	0	0	0
1560-89-0	Heptadecane, 2-methyl-	NA	1	1	0	0	0	0	1	0	0	0
163191-64-8	Phenyl-1-myrtenone, phenylethylimine	NA	1	1	0	0	0	1	0	0	0	0
1638-26-2	Cyclopentane, 1,1-dimethyl-	NA	1	0	1	0	0	0	1	0	0	0
17066-67-0	Naphthalene, decahydro-4a-methyl-1-methy…	NA	1	0	1	0	0	0	0	1	0	0
1719-06-8	Anthracene-D10-	NA	1	0	0	0	1	0	0	1	0	0
17361-53-4	4-Methoxycarbonylbutyl-3-methoxycarbonyl…	NA	1	1	0	0	0	0	0	1	0	0
17414-15-2	1-Butene, 1-(methylthio)-, (Z)-	NA	1	1	0	0	0	1	0	0	0	0
18362-97-5	Pentanoic acid, 1-methylethyl ester	NA	1	1	0	0	0	1	0	0	0	0
18979-55-0	Phenol, 4-(hexyloxy)-	NA	1	1	0	0	0	1	0	0	0	0
19258-27-6	3-Methopxybenz-4-nitrophenylhydrazon	NA	1	1	0	0	0	1	0	0	0	0
19871-46-6	2-Phenyl-1-phenylsulfonylaziridine	NA	1	1	0	0	0	1	0	0	0	0
21436-03-3	(1S,2S)-(+)-1,2-Diaminocyclohexane	NA	1	1	0	0	0	1	0	0	0	0
2175-91-9	1,3-Cyclopentadiene, 5-(1-methylethylide…	NA	1	0	0	0	1	1	0	0	0	0
21897-22-3	3',4',5'-Trimethoxyacetophenone isonicot…	NA	1	1	0	0	0	0	1	0	0	0
22445-43-8	2H-1,2-Oxazine,tetrahydro-2-methyl-	NA	1	1	0	0	0	1	0	0	0	0
2314-78-5	2,5-Pyrrolidinedione, 1-ethyl-	NA	1	1	0	0	0	0	1	0	0	0
2381-87-5	Dehydromevalonic lactone	NA	1	0	1	0	0	0	0	1	0	0
2452-99-5	Cyclopentane, 1,2-dimethyl-	NA	1	1	0	0	0	0	1	0	0	0

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Delaware Sand & Gravel Superfund Site
New Castle, Delaware

				Count of TIC Detections Per Event				Number of Wells with at Least 1 TIC Detection				
CAS Number	Compound	DNREC GW-SLV and/or USEPA RSL (ug/L)	Total Number of TIC Detections 2015-2016	Spring 2015	Fall 2015	Spring 2016	Fall 2016	DDA Vicinity - Columbia	Well PW-1(U) Vicinity - UPA and UPCUTZ	Well P-6/UPA-101 Vicinity - UPA and UPCUTZ	Down-gradient of Well PW-1(U) - UPA	NCC Monitor-ing Wells
2453-00-1	Cyclopentane, 1,3-dimethyl-	NA	1	0	0	1	0	0	1	0	0	0
26535-35-3	2H,8H-Benzo[1,2-b:5,4-b']dipyran-10-prop…	NA	1	1	0	0	0	0	1	0	0	0
27129-87-9	Benzenemethanol, 3,5-dimethyl-	NA	1	0	0	0	1	1	0	0	0	0
2870-04-4	Benzene, 2-ethyl-1,3-dimethyl-	NA	1	0	0	0	1	1	0	0	0	0
3166-54-9	Chloromethaqualone	NA	1	1	0	0	0	1	0	0	0	0
3415-89-2	7,10-Epoxy-6H-azepino[1,2-e]purine-8,9-d…	NA	1	1	0	0	0	0	1	0	0	0
3452-97-9	1-Hexanol, 3,5,5-trimethyl-	NA	1	1	0	0	0	1	0	0	0	0
35832-09-8	Pentamethylmelamine	NA	1	1	0	0	0	1	0	0	0	0
3622-84-2	Benzenesulfonamide, N-butyl-	NA	1	1	0	0	0	1	0	0	0	0
3878-55-5	Butanedioic acid, monomethyl ester	NA	1	0	1	0	0	0	0	1	0	0
3898-41-7	p-di-n-Propoxybenzene	NA	1	0	0	1	0	0	1	0	0	0
39255-32-8	Pentanoic acid, 2-methyl-, ethyl ester	NA	1	1	0	0	0	1	0	0	0	0
39815-78-6	Heptanoic acid, 3-oxo-, methyl ester	NA	1	1	0	0	0	0	0	1	0	0
41898-89-9	2,3-Heptadien-5-yne, 2,4-dimethyl-	NA	1	0	0	0	1	0	1	0	0	0
4437-22-3	Furan, 2,2'-[oxybis(methylene)]bis-	NA	1	0	1	0	0	0	0	0	0	1
4534-59-2	Benzene, (1-methyltridecyl)-	NA	1	0	0	0	1	0	0	0	0	1
4850-28-6	Cyclopentane, 1,2,4-trimethyl-, (1.alpha…	NA	1	1	0	0	0	0	1	0	0	0
488-17-5	1,2-Benzenediol, 3-methyl-	NA	1	0	1	0	0	0	0	1	0	0
503-86-6	4H-Imidazol-4-one, 2-amino-1,5-dihydro-	NA	1	1	0	0	0	0	0	0	1	0
51422-54-9	1-tert-Butoxy-2-ethoxyethane	NA	1	1	0	0	0	0	0	0	0	1
535-77-3	Benzene, 1-methyl-3-(1-methylethyl)-	NA	1	1	0	0	0	1	0	0	0	0
54833-23-7	Eicosane, 10-methyl-	NA	1	0	0	0	1	1	0	0	0	0
576-26-1	Phenol, 2,6-dimethyl-	1.1	1	0	1	0	0	1	0	0	0	0
585-74-0	Ethanone, 1-(3-methylphenyl)-	NA	1	0	1	0	0	1	0	0	0	0
5906-35-4	1H-Azepin-1-amine, hexahydro-	NA	1	1	0	0	0	1	0	0	0	0
591-24-2	Cyclohexanone, 3-methyl-	NA	1	0	1	0	0	0	0	1	0	0
61454-92-0	3,4-Epoxyhexanoic acid, ethyl ester	NA	1	1	0	0	0	0	0	1	0	0
61940-94-1	Diazene, [1-(2,2-dimethylhydrazino)-2-me…	NA	1	1	0	0	0	0	0	1	0	0
622-97-9	Benzene, 1-ethenyl-4-methyl-	NA	1	0	0	0	1	1	0	0	0	0
623-78-9	Carbamic acid, ethyl-, ethyl ester	NA	1	1	0	0	0	0	0	1	0	0
625-38-7	3-Butenoic acid	NA	1	0	0	0	1	1	0	0	0	0
626-97-1	Pentanamide	NA	1	1	0	0	0	0	0	1	0	0
627-73-6	Butanedioic acid, ethyl methyl ester	NA	1	1	0	0	0	0	0	0	1	0
6280-96-2	Phenol, 2-propoxy-	NA	1	1	0	0	0	0	1	0	0	0
629-92-5	Nonadecane	NA	1	0	0	0	1	1	0	0	0	0
630-02-4	Octacosane	NA	1	0	0	0	1	0	0	0	0	1
630-06-8	Hexatriacontane	NA	1	0	0	0	1	0	1	0	0	0
6351-10-6	1H-Inden-1-ol, 2,3-dihydro-	NA	1	0	0	0	1	1	0	0	0	0
6682-71-9	1H-Indene, 2,3-dihydro-4,7-dimethyl-	NA	1	0	1	0	0	1	0	0	0	0
6737-24-2	Acetic acid, hydroxy[(1-oxo-2-propenyl)a…	NA	1	1	0	0	0	0	1	0	0	0
67498-09-3	4-Hexenoic acid, 3-hydroxy-2-methyl-, me…	NA	1	1	0	0	0	1	0	0	0	0
7098-22-8	Tetratetracontane	NA	1	0	0	0	1	0	1	0	0	0
7116-86-1	1-Hexene, 5,5-dimethyl-	NA	1	1	0	0	0	1	0	0	0	0
75-98-9	Propanoic acid, 2,2-dimethyl-	NA	1	1	0	0	0	0	1	0	0	0
764-56-7	1,5-Heptadiyne	NA	1	1	0	0	0	0	1	0	0	0
7683-64-9	Squalene	NA	1	0	0	1	0	0	1	0	0	0
768-49-0	Benzene, (2-methyl-1-propenyl)-	NA	1	0	1	0	0	1	0	0	0	0
78-40-0	Triethyl phosphate	NA	1	0	1	0	0	1	0	0	0	0
78-51-3	Ethanol, 2-butoxy-, phosphate (3:1)	NA	1	0	0	0	1	0	0	0	0	1
79-17-4	Aminoguanidine	NA	1	1	0	0	0	0	1	0	0	0
80-39-7	Benzenesulfonamide, N-ethyl-4-methyl-	NA	1	1	0	0	0	1	0	0	0	0
80-46-6	Phenol, 4-(1,1-dimethylpropyl)-	NA	1	0	0	0	1	1	0	0	0	0
81-48-1	1-Hydroxy-4-(p-toluidine)anthraquinone	NA	1	1	0	0	0	1	0	0	0	0
816-19-3	Hexanoic acid, 2-ethyl-, methyl ester	NA	1	1	0	0	0	1	0	0	0	0
84-61-7	1,2-Benzenedicarboxylic acid, dicyclohex…	NA	1	0	0	0	1	0	0	0	0	1
874-35-1	1H-Indene, 2,3-dihydro-5-methyl-	NA	1	0	1	0	0	1	0	0	0	0
92-52-4	Biphenyl	0.083	1	0	1	0	0	1	0	0	0	0
93635-82-6	1,5-Anhydro-2-O-acetyl-3,4,6-tri-O-methy…	NA	1	1	0	0	0	1	0	0	0	0
97371-44-3	3-Buten-2-one, 3-methyl-4-(1,3,3-trimeth…	NA	1	1	0	0	0	0	0	0	1	0
998-93-6	4-Bromoheptane	NA	1	1	0	0	0	1	0	0	0	0
999-65-5	Butane, 1-(1-methylpropoxy)-	NA	1	1	0	0	0	0	0	1	0	0

Table A
Summary of 2015-2016 Tentatively Identified Compound Data
Delaware Sand & Gravel Superfund Site
New Castle, Delaware

				Count of TIC Detections Per Event				Number of Wells with at Least 1 TIC Detection				
CAS Number	**Compound**	**DNREC GW-SLV and/or USEPA RSL (ug/L)**	**Total Number of TIC Detections 2015-2016**	**Spring 2015**	**Fall 2015**	**Spring 2016**	**Fall 2016**	**DDA Vicinity - Columbia**	**Well PW-1(U) Vicinity - UPA and UPCUTZ**	**Well P-6/UPA-101 Vicinity - UPA and UPCUTZ**	**Down-gradient of Well PW-1(U) - UPA**	**NCC Monitor-ing Wells**
TIC_UNK	Unknown TICs	NA	790	64	164	285	277	NA	NA	NA	NA	NA

Notes:

1) TIC = Tentatively Identified Compound
2) DNREC-GW-SLV = Delaware Department of Natural Resources and Environmental Control Screening Level Value updated July 2016, these standards are equal to the United States Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs).
3) CAS = Chemical Abstracts Service
4) DDA = Drum Disposal Area
5) UPA = Upper Potomac Aquifer
6) NCC = New Castle County
7) UPCUTZ = Upper Potomac Confining Unit Transition Zone
8) ug/L = micrograms per liter
9) NA = Not Applicable
10) "…" Indicates TIC compound name truncated due to database character limitations
11) Unknown TICs represent compounds for which the relative intensity of the major ions in the sample spectra did not compare to the NIST (National Institute of Standards and Technology) reference spectra library with sufficient quality to support identification.

Table B
Summary of 2015-2016 Frequently Detected Tentatively Identified Compound Data By Well
Delaware Sand & Gravel Superfund Site
New Castle, Delaware

Maximum Estimated Concentration (see Note 4) — DDA Extraction Wells

CAS Number	Compound	DNREC GW-SLV and/or USEPA RSL (ug/L)	Total Number of TIC Detections 2015-2016	Count of TIC Detections Per Event: Spring 2015	Fall 2015	Spring 2016	Fall 2016	B-4DR	BG-1	C-18D	C-19D	C-20D	C-2D	C-30	C-4D
496-11-7	Indane	NA	111	37	22	30	22	130	26	32		5.6	21	6.5	93
526-73-8	Benzene, 1,2,3-trimethyl-	1	108	35	23	30	20	67	44	86				15	190
611-14-3	Benzene, 1-ethyl-2-methyl-	NA	75	27	15	22	11	160	17	43				5.3	140
620-14-4	Benzene, 1-ethyl-3-methyl-	NA	67	20	13	16	18	28	13	61				11	140
100-61-8	Aniline, N-methyl-	3.8	32	6	7	11	8		13						17
1205-91-0	1,4-Benzenediol, diacetate	NA	31	19	3	6	3	890	28						110
4812-20-8	2-Isopropoxyphenol	NA	29	9	7	10	3	68							
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-	NA	24	5	6	9	4	130	16						10
1025-15-6	Triallyl isocyanurate	NA	21	3	4	8	6	190	39						26
75-43-4	Fluorodichloromethane	NA	21	4	6	6	5								
827-16-7	1,3,5-Trimethylcyanuric Acid	NA	17	9	6	1	1	130	12						19

DDA Monitoring Wells

CAS Number	Compound	B-2D	B-3D	C-1D	C-22S	DGC-7C	DGC-8C	GA-101	MHW-1M	MHW-1S	P-4D	PZ-11-EXT	PZ-4-INTR	PZ-6N	PZ-6S
496-11-7	Indane	5	80	28			9.6	410				430	31		69
526-73-8	Benzene, 1,2,3-trimethyl-		110	26				930			12	1200	30		520
611-14-3	Benzene, 1-ethyl-2-methyl-		29	13				730				790	24		240
620-14-4	Benzene, 1-ethyl-3-methyl-		43					2200				560	50		410
100-61-8	Aniline, N-methyl-		10							22					
1205-91-0	1,4-Benzenediol, diacetate		32												
4812-20-8	2-Isopropoxyphenol		13												
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-														
1025-15-6	Triallyl isocyanurate		10	19						11					
75-43-4	Fluorodichloromethane		8.7												
827-16-7	1,3,5-Trimethylcyanuric Acid														

PW-1(U) Monitoring Wells

CAS Number	Compound	DDA-05	DDA-06	DDA-07-TZ	DDA-08-TZ	DDA-09-TZ	DDA-12-TZ	DDA-13-TZ	DDA-14-TZ	DDA-15-TZ	DDA-16-TZ	DDA-07-US	DDA-10-US	DDA-11-US	DDA-12-US	DDA-17	DGC-2S	DGC-5	DGC-7S	PW-1(U)
496-11-7	Indane	160	51	33		26	80	5.9	7.6	100			8.8		61					7.7
526-73-8	Benzene, 1,2,3-trimethyl-	280				53	70			130	68		15		200					9.2
611-14-3	Benzene, 1-ethyl-2-methyl-	190				28	68			160			5.1		49					8.8
620-14-4	Benzene, 1-ethyl-3-methyl-	260				19	35		5.3	110			11		160					21
100-61-8	Aniline, N-methyl-					11	86	50					30							
1205-91-0	1,4-Benzenediol, diacetate		110			38	320			200			8.9		19					
4812-20-8	2-Isopropoxyphenol		27			8.8	130			61			52							
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-		30	8.4		9.5	69	18		43					9.4					
1025-15-6	Triallyl isocyanurate		17	19		11	36			41					30					
75-43-4	Fluorodichloromethane						13	13					16							
827-16-7	1,3,5-Trimethylcyanuric Acid		61			14	90								16					

P-6/UPA-101 Vicinity, Downgradient UPA Wells, NCC UPA Monitoring Wells

CAS Number	Compound	P-6_UPA	UPA-101-TZ	UPA-101-US	AWC-E1	AWC-E2	DGC-10D	DGC-10S	DGC-11S	DGC-8D	DGC-8S	RT-1-UP	UPA-01	UPA-02D	UPA-02S	UPA-03D	AWC-K1	BW-1	BW-2	MW-18	MW-26N	MW-28	MW-29	MW-31	MW-34	P-4_UPA	P-5L
496-11-7	Indane	19	12	35									15														
526-73-8	Benzene, 1,2,3-trimethyl-	75	25	35																							
611-14-3	Benzene, 1-ethyl-2-methyl-	36	28	32																							
620-14-4	Benzene, 1-ethyl-3-methyl-	56		24																							
100-61-8	Aniline, N-methyl-	67	140	49		9.6							28								13						
1205-91-0	1,4-Benzenediol, diacetate	26	37	32									16														
4812-20-8	2-Isopropoxyphenol	450	390	200									79														
611-92-7	Urea, N,N'-dimethyl-N,N'-diphenyl-	24		31									9.4														
1025-15-6	Triallyl isocyanurate																										
75-43-4	Fluorodichloromethane	22	60	23									13														
827-16-7	1,3,5-Trimethylcyanuric Acid	64		71		7.1							14								8.8						

Notes:
1) CAS = Chemical Abstracts Service
2) TIC = Tentatively Identified Compound
3) DNREC-GW-SLV = Delaware Department of Natural Resources and Environmental Control Screening Level Value updated July 2016, these standards are equal to the United States Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs).
4) Estimated TIC "concentrations" cannot be compared to numerical standards because the actual calibrated concentrations for these compounds have the potential to be orders of magnitude higher or lower than the estimated TIC concentrations.
5) DDA = Drum Disposal Area
6) UPA = Upper Potomac Aquifer
7) NCC = New Castle County
8) ug/L = micrograms per liter
9) NA = Not Applicable